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THE BELT DYNAMOMETER OF DOCTOR C. W. SIEMENS.

By ROBT. BRIGGS, C.E.

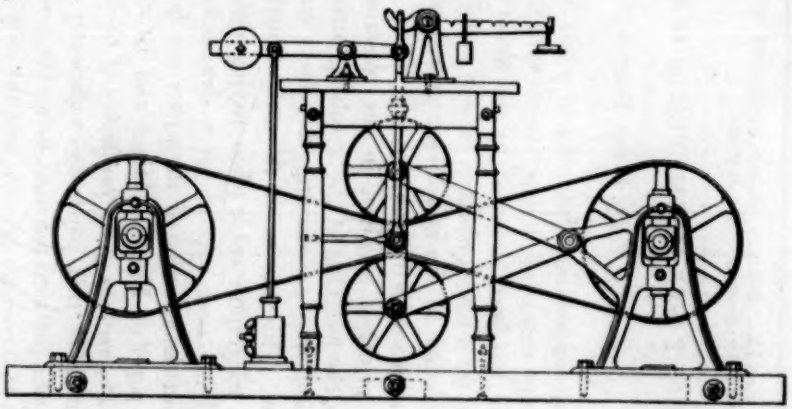
The accompanying illustration of a belt dynamometer after the general design employed in experiments with the Siemens dynamo-electric machine, has been prepared by the writer of this article, to meet the demand for a more quiet and equally reliable instrument of this kind than is found in the well-known geared or tooth-wheel dynamometer in common use in this country.

The principle involved in the construction of this dynamometer, that is, the weighing of the resulting stress from a deflected cord or band, and thus ascertaining the direct stress upon the band itself, is not new. This was one of the earliest methods of measuring the load upon a telegraphic cable when paying out, and it is believed that the method has been applied for a dynamometer in Germany for some time, but the attention of the writer was first brought to it by perusal of the paper of Messrs. Higgs and Brittle on Electrical Apparatus, in the *Proceedings of the Institution of Civil Engineers for* 1878. The illustration in that paper was sufficiently good for any mechanic to work out a practical machine, using the general details of shafting and pulleys of American practice, and the only *improvement* or novelty now presented consists in thus adapting the machine of Dr. Siemens to American convenience.

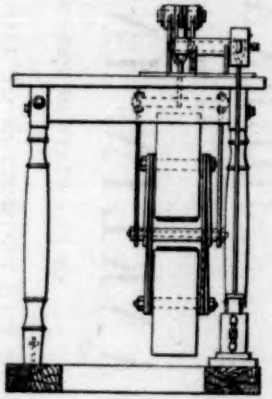
BELT DYNAMOMETER

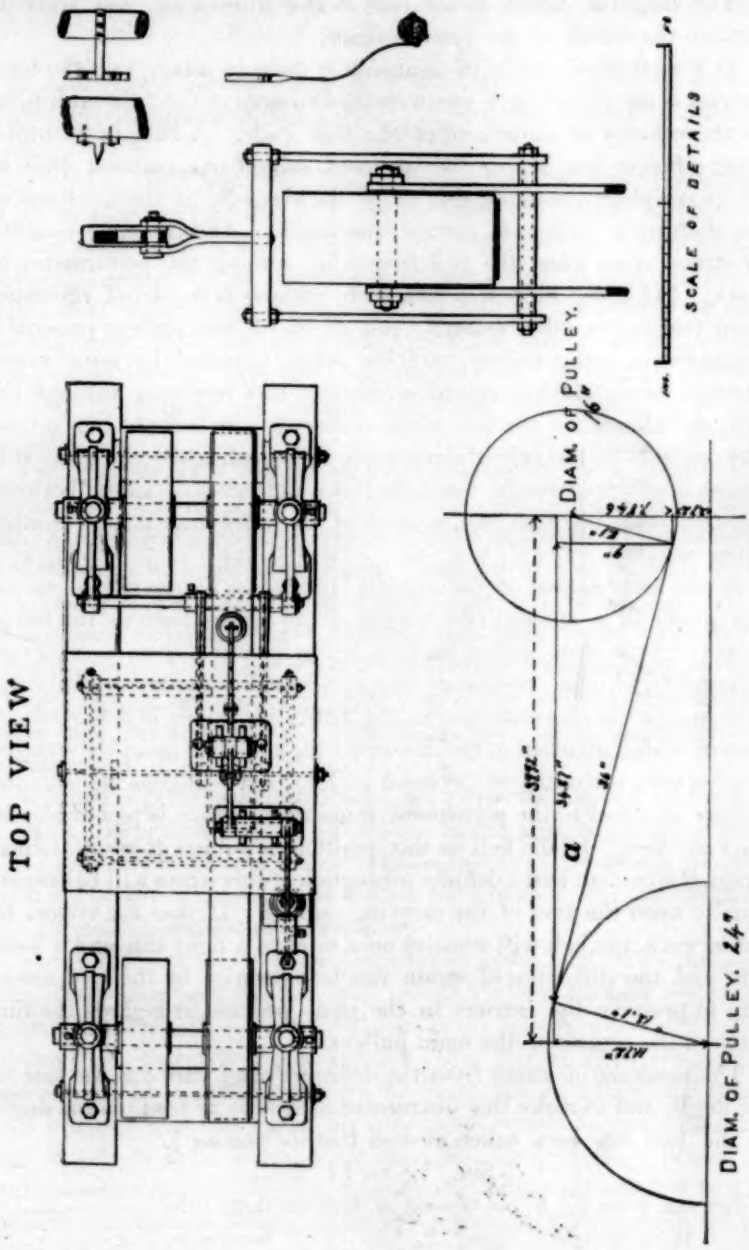
SCALE.

SIDE ELEVATION



END VIEW
HANGERS REMOVED




SCALE OF DETAILS
TOP VIEW
DIAM. OF PULLEY.
DIAM. OF PULLEY. 24"

The diagram, which forms part of the illustration, will serve to explain the theory of the dynamometer.

It is established in the transmission of force by a belt, that the force exerted is the difference of strain on the two sides of the belt, multiplied by the velocity of movement of the belt itself. A belt, in its initial state, when at rest, is a continuous band, subject to a uniform strain in all its periphery, bringing into action the elasticity of the band and of the shafting or pulleys to sustain this strain. And the same equality of strain exists when the belt is running without the performance of work. [It being supposed that such running is devoid of resistance from friction or other cause.] But as one of the pulleys presents a resistance to being turned, and the other, impelled by some motor through its shaft, takes up and overcomes this resistance through the belt, the adhesion of the belt to the pulleys is now brought into action, and one side of the belt is abnormally tightened, while the other side becomes correspondently loose, and the difference of strain between the two sides becomes the measure of the force transmitted at some given velocity.

In the arrangement of pulleys and belt shown by the side elevation (see plate), it is obvious (the weight of the carrier pulleys, the frame supporting the same, and of the belt, being balanced) that when at rest or running with no resistance the system will come into equilibrium with equal but opposite angles for both the upper and lower belt. The indicator, attached to the carrier frame, will then be in the straight line between the centre of the main pulleys, and will coincide with the pointer attached to the permanent framework, which is placed also in the same line. If the belt in this position be subject to some normal strain, it is evident that a definite proportion of this strain will be exerted equally upon the axes of the carrying pulleys. If now the system be put at work, the belt will come at once to have a tight side and a loose side, and the difference of strain can be measured by the load necessary to preserve the carriers in the same position as regards the line between the centres of the main pulleys.

The resultant of strain from the deflected band varies as the sine of the angle, and to make this instrument as simple as possible the angle of the belt has been taken as such that its sine $= \frac{1}{4}$.

$$[\text{Sin.}^{-1} \tfrac{1}{4} = 14^\circ\ 29'.]$$

Let sin. $a = \frac{1}{4}$; T_1 = tension of belt on tight side.

W = weight; T_2 = " " loose side.

P = force transmitted.

$$\therefore \qquad P = T_1 - T_2 = \frac{W}{2 \sin. a} = 2\ W$$

If, therefore, a certain force, W, is needed to preserve the central position of the indicator, there will have been transmitted by the belt a force $= 2\ W$.

Accepting these relations of angles and force, the relative positions of an arrangement which shall employ pulleys 24 inches in diameter for the main pulleys, and others 8 inches in diameter for the carrier pulleys, is given by the diagram, when the length of inclined belt is taken at 36 inches. An allowance of $\frac{1}{16}$ inch has been made for half the thickness of the belt when the radii of the line of the belt on the two pulleys become $12\frac{1}{16}$ and $8\frac{1}{16}$, respectively. It will be easy for any one to compute the triangle and verify the dimensions on the diagram.

The machine itself consists of a bed framing of wood, joint-bolted together, upon which is mounted a high table, also joint-bolted throughout. The bed frame carries two pairs of inverted hangers, $2\frac{1}{4}$-inch shaft, 20-inch drop, with self-oiling boxes. Each pair of hangers carry shafts $2\frac{7}{16}$ inches of diameter, with two pulleys, 24×7 inches, high. One of the pairs of hangers have brackets cast upon them, which form the fulcrum for the carrier frame. The carrier frame has two pulleys, 16×7 inches, high, and the pulley end of the frame is suspended by knife-edge pins and links to a scale beam, the P of which has half the usual weight.

With this P the scale indicates the strain transmitted by the belt without computation. The suspension frame, also, is hung by well-fitted pins and links to a counterbalance system of levers and weights, with a dash pot attachment to control the action of the dynamometer against sudden variations of work.

This dynamometer, with the proportions given, and on the supposition that 6-inch belts be used, will transfer, where the belt is strained normally upon both sides to 40·4 pounds per inch of width, 7·2 horse-power. As, however, the contact with the driving or driven pulleys can scarcely be so great as that on the main pulleys, where 210° exists, it is probable that this particular instrument cannot be held to measure the transmission of much more than $6\frac{1}{2}$ horse-power. When the unbalanced strain of the two sides of the belt must amount to 47·4 pounds per inch of width, while the actual maximum strain on the tight side of the belt cannot be less 56 to 60 pounds, and may much exceed that value if the normal strain rises above 40 or 42 pounds.

HIGH RAILWAY SPEEDS.

By W. Barnet Le Van.

Read before the Franklin Institute, at its meetings, May 19th and June 15th, 1880.

Railways being now the common highways of our country, their managers naturally seek all means of accommodating and meeting the wants of the traveling community.

The active rivalry now existing between the Pennsylvania Railroad and the Bound Brook Route of the Philadelphia and Reading Railroad has resulted in giving us the most improved facilities for communication between the two principal cities of this country, and has placed our railway speed on a par with the fast time of the British express trains.

It is but a few years ago that a trip to New York and back in the same day was considered a wonderful achievement; the time occupied, being three hours each way, was thought very short, whereas to-day one can have his breakfast and go to New York, transact business and return and dine in his own house. But even the great reduction of time has not been considered sufficient to comply with the requests of rapid transit, and the two roads referred to are contemplating and preparing to run the 90 miles between Philadelphia and New York in 90 minutes.

Sixty miles an hour, as it strikes the ear, does not seem an impossibility, but if we look at it in all its bearings, and consider that it means *one mile in one minute*, or 60 *miles in* 60 *consecutive minutes*, it begins to assume proportions that seem insurmountable.

Some of the earliest locomotives ever built have run over a mile a minute, and in one instance a speed of 93 miles per hour was maintained for a few miles.

To illustrate more clearly the difficulties in running sixty miles in sixty minutes, the locomotive must be capable at all times of developing *seventy miles per hour*, so as to meet any contingency that may arise. A locomotive at seventy miles an hour passes over one hundred and two feet per second $\left(\frac{70\times22}{15} = 102{\cdot}6\right)$. Two objects near a person, say three feet apart, pass his eye in the thirty-fifth part of a second.

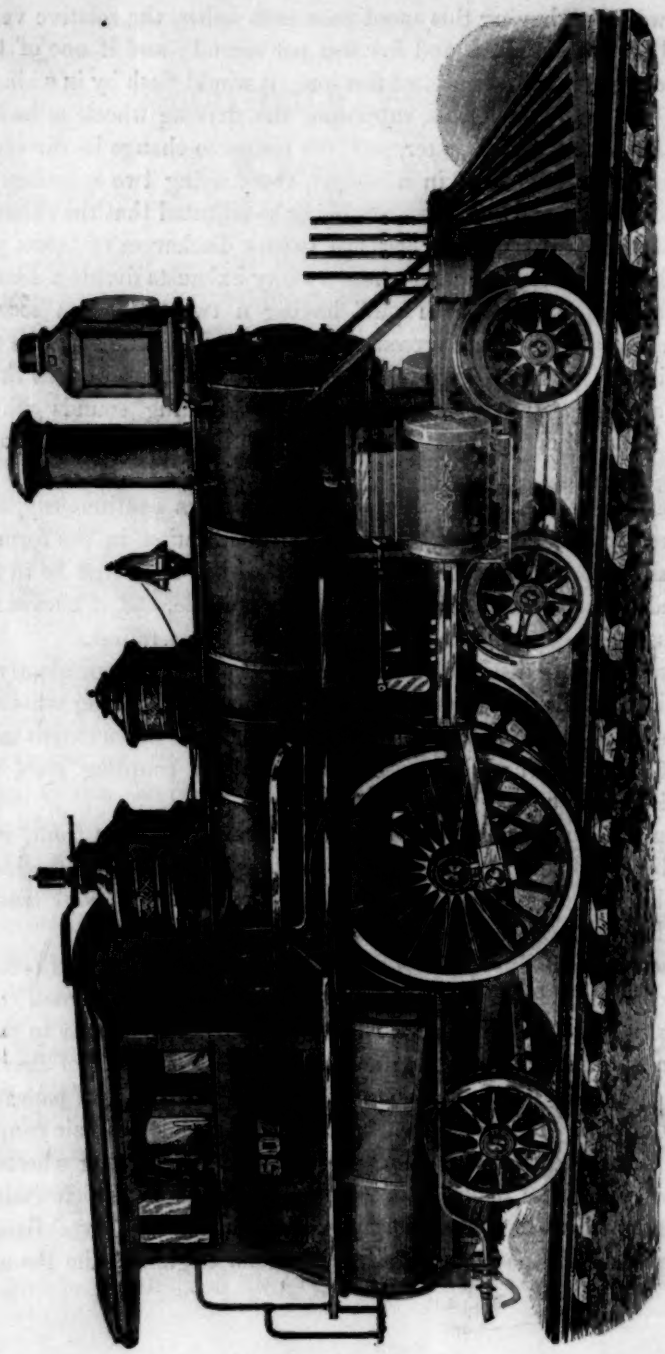
When two trains having this speed pass each other, the relative velocity will be two hundred and five feet per second; and if one of the trains were one hundred and two feet long, it would flash by in a single second. To accomplish this, supposing the driving wheels to be six and one-half feet in diameter, and the piston to change its direction in the cylinder ten times in a second, there being two cylinders to every locomotive, and the eccentrics being so adjusted that the exhaust steam discharges alternately, there are twenty discharges of steam per second, at equal intervals, and these twenty exhausts divide a second into twenty equal parts, each puff having a twentieth of a second between it and that which precedes and follows it. The ear, like the eye, is limited in the rapidity of its sensations; and, sensitive as those organs are, they are not capable of distinguishing sounds which succeed each other at intervals as short as the twentieth part of a second.

Therefore, to run sixty miles in sixty minutes continuously, and with a reasonable degree of safety, some modification in the form of engine as now built must be made. The road bed must also be in the best condition attainable, and as straight as possible, and if curves are indispensable they should not be less than 2000 feet radius.

Locomotives are distinguished as *single* or *coupled*, independently of their kind or class. When only a single pair of driving wheels is employed, the engine is said to be a single engine. When two or more pairs of driving wheels are used, connected by coupling rods, the engine is said to be coupled.

When six coupled wheels and a swing "pony truck" in front, connected by equalizing beams with the leading pair of coupled wheels, it is called *Mogul*, and when eight coupled wheels and "pony truck" it is called *Consolidation*.

To accomplish sixty miles in sixty minutes, the Baldwin Locomotive Works, of this city, have just placed on the Bound Brook route between this city and New York a new single engine, similar to those used on the fast lines in England, having but one pair of driving wheels, 6½ feet in diameter. The ordinary driving wheels of passenger engines in this country do not exceed 5½ feet, and two pair coupled together, are used. For fast speeds, with coupled driving wheels, as in ordinary use, the momentum of the parallel rods which connect the driving wheels becomes enormous, and is a source of great danger. Within a month past the parallel rod of an engine on the Pennsyl-



Locomotive No. 5000, built by the Baldwin Locomotive Works.

vania Railroad broke. It demolished the cab of the engine, and seriously injured the engineer, and detained the train over one hour.

This new engine requires no parallel rods, and the increased diameter of the wheels also reduce the number of revolutions to the mile, as well as the centrifugal force.

In the ordinary locomotive with small and coupled driving wheels, the greatest speed of the piston reaches sometimes about 1200 feet per minute with a 2 foot stroke and 5½ feet diameter driving wheels, giving about fifty-nine miles per hour; but with driving wheels 6½ feet diameter, and the same piston speed, the running rate would be about *sixty-nine miles* per hour. No more adhesion is required at high than at low speeds, assuming the load to be the same. The truth is that the amount of adhesion required to turn to account the whole power which a locomotive is capable of developing varies, inversely, according to the speed at which the engine is run, the higher the speed the less being the adhesion required. The increased resistance, according to experiments made, is in a less ratio than that of the simple velocity, so that the boiler need not exceed the limit of space afforded. The ordinary locomotive boilers do not exceed 1100 feet of heating surface and 20 square feet of fire grate. In this new locomotive the boiler has about 1400 square feet of heating surface and about 56 square feet grate surface.

The dimensions of the engine are as follows:

Diameter of cylinders, in inches,	18
Length of stroke, in inches,	24
Diameter of driving wheel, in inches,	78
Wheel-base, in feet,	21 ft. 1 in.
Distance from centre of driving wheel to centre of trailing wheel, in feet,	8

BOILER.

Boiler made of steel $\frac{7}{16}$ inch in thickness.
Diameter of boiler, 52 inches.
Number of tubes, 198 and 2 inches diameter.
Length of tubes, 12 feet 2¾ inches.
Fire-box, 96½ long by 84 inches.

TENDER.

Capacity about 3800 gallons.
Wheels, 36 inches diameter.
Weight, filled with water and coal, 70,000 pounds.

The Bound Brook road is not fitted with water troughs between the tracks, so that the locomotive tender can pick up its water while in motion; thus, larger tenders are needed to convey sufficient water for the through trip.

By dispensing with the coupling rods and reducing the centrifugal force of the driving wheels it is evident that the design of the engine is in the right direction for safety and fast running.

The tractive force for each pound of effective pressure per square inch on the pistonswhich this engine is capable of exerting will be

$$\frac{18^2 \times 24}{78} = 99{\cdot}68 \text{ pounds.}$$

In running sixty miles per hour, on an ordinary road, which corresponds to about 258 revolutions, or a piston speed of 1034 feet per minute, and a mean effective pressure of about 35 pounds per square inch, the tractive power exerted will be

$$\frac{18^2 \times 24 \times 35}{78} = 3489 \text{ pounds}$$

for each piston, and the horse-power for the two cylinders will be

$$HP = \frac{18^2 \times 1034 \times 35}{33000} \times 2 = 552{\cdot}72$$

To run a train sixty miles in sixty minutes between Philadelphia and New York would not be considered as remarkable, provided the track was always clear; but several large towns, cities, and bridges, some of which have draws, are, however, scattered along the route, necessitating a material reduction of speed in passing them, and thus time is lost, which must be made up by a proportionate increase in speed on those parts of the roadway which are clear and unobstructed. This increased speed must be as great, at times, as *seventy miles* an hour, as before stated.

On Friday, May 14th, 1880, I received an invitation from Messrs. Burnham, Parry, Williams & Co., to make a trip on a train to be drawn by their "new departure locomotive, No. 5000," the 5000th of their build (Philadelphia and Reading Railroad Company's No.

507), from Ninth and Green streets to Jersey City, over the Bound Brook route, without stopping, and return in the same way.

As before stated, this locomotive has only one pair of driving wheels, 78 inches in diameter.

The weight is so disposed upon the wheels that by an alteration of fulcrum, points operated by a separate steam cylinder additional weight can be thrown on the drivers at the time of starting. This shifting of the weight will give from 8000 to 9000 pounds additional on the driving wheels.

The weight of the engine, ready for attaching to the train, is 85,000 pounds, and the tender 70,000. The train going to New York consisted of four day (set up) cars, of the usual pattern, each weighing about 42,000 pounds. Weight of the train complete, about 148 tons.

The Start.

When the engine left the round house, to take its place at the head of the train, I was reminded of what Elihu Burritt says, when writing about the locomotive:

"I love to see one of those huge creatures, with sinews of brass and muscles of iron, strut forth from his stable and salute the train of cars with a dozen sonorous puffs from his iron nostrils, then fall back gently into his harness.

"There he stands champering and foaming upon the iron track, his great heart a furnace of glowing coals, his lymphatic blood boiling within his veins; the strength of a thousand horses is nerving his sinews, he pants to be gone. He would drag St. Peter's across the Desert of Sahara, if he could be hitched on."

The signal to go ahead was given at precisely 11.16 A.M., and, on account of Ninth street being more or less obstructed by teams crossing, 9½ minutes was consumed in reaching Wayne Station, distance, 4·3 miles, rate of speed, per hour, 27·15 miles.

Wayne Station to Jenkintown, distance 5·8 miles, time 6·75 minutes, rate of speed 51 miles per hour.

Jenkintown to Yardley, distance 20 miles, time 19 minutes, rate of speed 63 miles per hour.

Yardley to Trenton Junction, distance 2 miles, time 2¼ minutes, rate of speed 53·3 miles per hour.

Trenton Junction to Bound Brook, distance 27·1 miles, time 25¾ minutes, rate of speed 63 miles per hour.

Bound Brook to Elizabeth, distance 20·7 miles, time 20¾ minutes, rate of speed 60 miles per hour.

Elizabeth to Jersey City, distance 11½ miles, time 14 minutes, rate of speed 49·3 miles per hour.

Total time from Ninth and Green streets, Philadelphia, to Jersey City, 89·4 miles, 98 minutes, rate of speed 54·73 miles per hour.

The Return.

On the return trip one car was added, making the total load 168 tons.

Left Jersey City at 2.07 Philadelphia time, reached Elizabeth at 2.21½, distance 11½ miles, time 14½ minutes, rate of speed 47½ miles per hour.

Elizabeth to Bound Brook, distance 20·7 miles, time 19 minutes, rate of speed 65·3 miles per hour.

Bound Brook to Trenton Junction, distance 27·1 miles, time 26·8 minutes, rate of speed 60·6 miles per hour.

Trenton Junction to Yardley, distance 2 miles, time 2½ minutes, rate of speed 53 miles per hour.

Yardley to Jenkintown, distance 20 miles, time 20·8 minutes, rate of speed 57·6 miles per hour.

Jenkintown to Wayne Junction, distance 5·8 miles, time 8 minutes, rate of speed 43·5 miles per hour.

Wayne Junction to Ninth and Green streets, distance 4·3 miles, time 8½ minutes, rate of speed 30·3 miles per hour.

Total time from Jersey City to Ninth and Green streets, Philadelphia, 100 minutes, distance 89·4 miles, rate of speed 53·4 miles per hour.

The best performance during the trip was in running the 2·8 miles from Willitt to Langhorne, part of which distance is an ascending grade of 16 feet per mile, in two minutes, being at the rate of *eighty-one miles per hour.*

A careful examination of all the bearings at the end of each trip showed them to be perfectly cool, which is something extraordinary for a new engine, running 90 miles without stopping.

To show the speed this engine is capable of performing, on a former trial she ran 13·8 miles in 10½ minutes, or at the rate of *seventy-eight and eighty-five hundredths* of a mile per hour.

Some idea of the steaming capacity of the boiler may be had from

the fact that a No. 9 Sellers injector, which will throw 2000 gallons of water per hour, will not keep her supplied.

The water consumed in the 98 minutes' run to Jersey City was about 3300 gallons, and on the return trip about 3600 gallons, or about 34½ gallons, or 288 pounds per minute.

Comparing this time with the fast time made by the 7.35 A. M. going east and the 3.30 P. M. coming west, on the Pennsylvania Railroad, from Germantown Junction to Jersey City and return, we have as follows:

PENNSYLVANIA RAILROAD.—Germantown Junction to Jersey City, distance 84·2 miles, time 106 minutes, rate of speed 47·7 miles per hour.

READING RAILROAD.—Wayne Junction to Jersey City, distance 85·1 miles, time 88½ minutes, rate of speed 57·6 miles per hour.

Jersey City to Germantown Junction, distance 84·2 miles, time 103 minutes, rate of speed 49 miles per hour.

Jersey City to Wayne Junction, distance 85·1 miles, time 91½ minutes, rate of speed 55·7 miles per hour.

Being seventeen per cent. less time going east and twelve per cent. coming west than that now made by the Pennsylvania Railroad.

The advantage of large diameter for driving wheels is in the reduction of the number of revolutions per mile. In the Baldwin engine the revolutions per mile are $\frac{1680}{6{\cdot}5} = 258$, and those of the Pennsylvania Railroad, with a 5½ foot wheel, $\frac{1680}{5{\cdot}5} = 305$, an increase of $\frac{305 - 258 \times 100}{305} = 15{\cdot}4$ per cent., and their engines being coupled, this additional number of revolutions adds to the risk by increasing the momentum of the parallel rods and tending to separate them.

It must not be supposed that 80 miles an hour is the limit of speed which a railway train may attain. Speed is a question of power and resistance, and velocities greater than 80 miles an hour, which is about 7000 feet per minute, are in use in various kinds of machinery, to wit: fan-blowers, circular saws, etc.

The writer believes that before the expiration of five years, with the present active rivalry, passengers will be set down in New York in one hour's time from this city.

The following table shows the speed in miles per hour of the *fast lines* in Europe and America.

DESTINATION.		Name of Railway.	Distance between stations in miles.	Time between stations, hours and minutes.	Av. miles per hour inc. stops.
Paris to	Marseilles,	....	539	15·21	35
	Lyons,	....	320	8·	40
Berlin to	Cologne,	....	364	9·26	38½
	Magdeburg,	....	88¾	2·7	42
Spandau to	Stendal,	Berlin & Hamb'g	57½	1·22	42
London to	Edinburgh,	Great Northern	397	9·30	42
	Plymouth,	London & S. W.	246½	6·15	41
	Holyhead,	North-Western	268	6·35	43
	Swindon,	Great Western	77¼	1·27	53½
	Rugby,	North-Western	82¼	1·42	48½
	Leicester,	Midland	99	2·13	44½
	Peterborough,	Great Northern	76¼	1·32	50
New York to	Philadelphia,	Penna. R.R.	90	2·05	43
	Washington,	"	230	6·	38
	Boston,	"	233	7·11	32
	Cincinnati,	"	757	26·30	28
	Pittsburg,	"	444	13·30	32
	Chicago,	"	912	34·20	26½
	Albany,	Hudson River	143	4·05	35
	Philadelphia,	Bound Brook	90·4	2·10	41½
Jersey City to	Wayne Junc.	"	85·1	1·47	47
	Gemant'n "	Penna. R.R.	84·2	1·43	49
Philadelphia to Chicago,		"	822	23·50	35

The mean average of all the English railways is 46·2 miles per hour; French, 37·5 miles per hour; German, 40 miles per hour, and America, 37 miles per hour. The English being 20 per cent. faster than in this country.

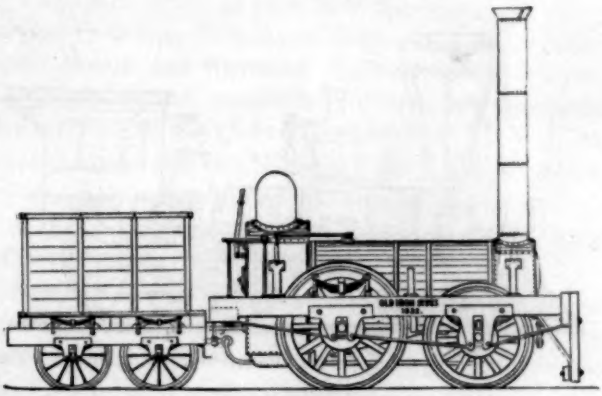
With them, 6½ feet driving wheels are quite as common as 5½ feet wheels are with us; in fact some of the fast lines have 8 and 9 feet, and one line had 10 feet diameter.

Engines with one pair of drivers are not new in this country. The *Ironsides*, built by M. W. Baldwin in 1832, had but one pair of drivers, 4½ feet in diameter. Mr. William Pettit ran her on the Phil-

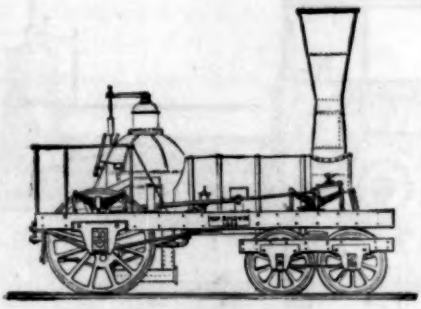
adelphia and Germantown Railroad at the rate of 62 miles per hour. Dr. Patterson, of the University of Virginia, and Mr. Franklin Peale were on the engine, and timed its working on that occasion.

In 1849 Edward S. Norris, of Schenectady, built for the then Utica and Schenectady Railroad the *Lightning*, Crampton, with 16 inch cylinders, 22 inch stroke, and a single pair of 7-feet wheels, which ran at the rate of 60 miles an hour in the year 1850, but it only worked a short time.

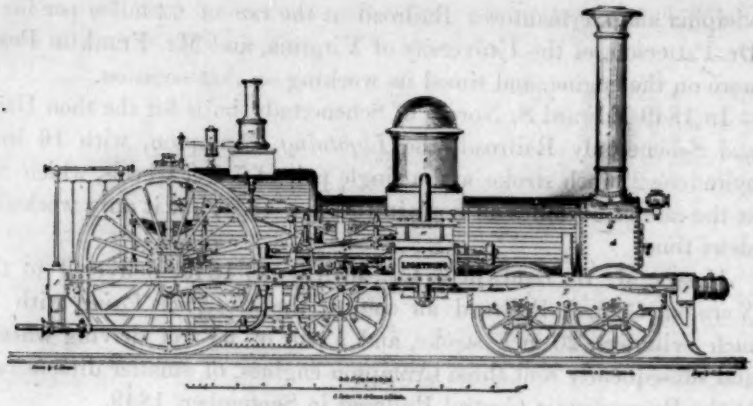
Messrs. M. W. Baldwin & Co., in August, 1849, delivered to the Vermont Central Railroad an engine, the *Governor Paine*, with 17 inch cylinders, 20 inch stroke, and a pair of 6½ feet driving wheels, and subsequently sent three Crampton engines, of smaller dimensions, to the Pennsylvania Central Railroad in September, 1849.



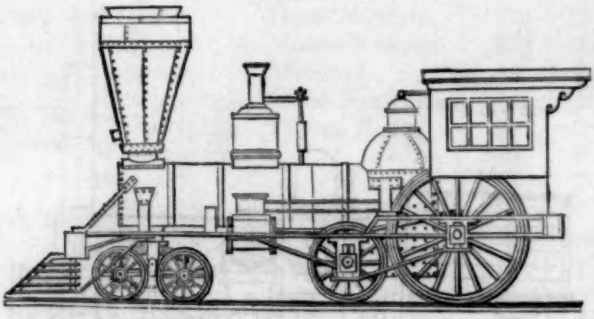
Old Ironsides, 1832.



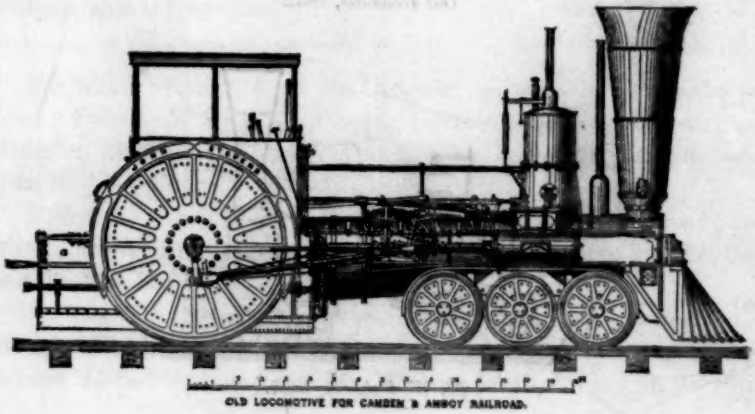
M. W. Baldwin, 1837.



Lightning, 1849.



Governor Paine, 1849.



OLD LOCOMOTIVE FOR CAMDEN & AMBOY RAILROAD.

Norris Brothers made seven engines for the Camden and Amboy Railroad, each with a single pair of 8 feet driving wheels, and a six-wheeled truck. The first of these, with 13-inch cylinders and a 34-inch stroke, was sent from the makers' shops April 17th, 1849. The next of the class had 13×38-inch cylinders, and were delivered Dec., 1849. The last of the series, delivered in April, 1853, had 14-inch cylinders and a 38-inch stroke. The 13-inch cylinders weighed, empty, 40,754 pounds, and loaded, 49,253 pounds. Of the weight loaded, 18,496 pounds, or about $8\frac{1}{4}$ tons, were on the driving wheels, with about $13\frac{3}{4}$ tons on the truck, making 22 tons in all. These engines had boilers 36 inches in diameter, with plates but $\frac{3}{16}$ inch thick.

In 1850 they also built two outside cylinder engines, with 14-inch cylinders, 32-inch stroke, and coupled 7-feet driving wheels, for the New York and Erie Railroad (new Erie Railway).

In the year 1849 Ross Winans, of Baltimore, built a single locomotive for the Boston and Worcester Railroad. It was for an experiment in coal-burning and constructed to burn anthracite coal. This locomotive was named the *Carroll of Carrollton*. It had one pair of 7-foot driving wheels and was intended for very high speed. It had two small steam cylinders placed on the sides of the boiler, over the bearings of the driving axle, by which the weight on the drivers could be varied from three to twelve tons.

The 7-foot drivers were cast with chilled rims and were of extremely light pattern; in fact they became broken after running six weeks. These were replaced with a set of imported wrought iron wheels, the first of the kind brought to this country.

The speed of the engine, under favorable circumstances, was one mile in sixty seconds. It was run between Albany and Boston, and the train consisted of from seven to eight cars, and made a mile a minute with ease. The engineer, J. H. Jackman, says: "Since I run her in 1849, I have traveled many thousand miles on locomotives, and have seen some high speeds made, still I have never seen the locomotive that could lay right down to it and out-run the *Carroll of Carrollton*. When I run her we made many stops, and therefore could not make better time than locomotives having smaller driving-wheels. But give me fifty or sixty miles on a clear run, and I could out-run a thunder storm if it was going our way. In those days we had no air-brakes, and to run at such high rates of speed sometimes became dangerous. I remember one instance, in the night-time, of rounding a

curve at about sixty miles per hour, when a danger signal met my view. I shut off steam and whistled down brakes, but they did not seem to check me. I whistled again; still the speed kept up. I gave the third signal for brakes, and then reversed my engine, saying to her 'Do your duty, my beauty, or in twenty seconds it is good-bye to railroading.' We came to a stand-still eighty rods from a train on the main track, having run one mile and a quarter from the place where I first discovered the red light. A locomotive engineer, to avoid trouble, must take time by the forelock—in other words, must anticipate possibilities."

Not over a dozen and a half of single engines have been made in the United States. Smaller wheels have been substituted for nearly all of these engines, from the fact that all the large-wheeled engines had small boilers, and with a single pair of driving wheels the adhesion was in all cases insufficient for the want of a proper distribution of the weight excess, as in the case of the *Carroll of Carrollton*, and, as before stated, the adhesion weight could be varied between three and twelve tons.

The present Baldwin has a similar arrangement, as before described, also the great advantage of a large boiler with ample heating and grate surface.

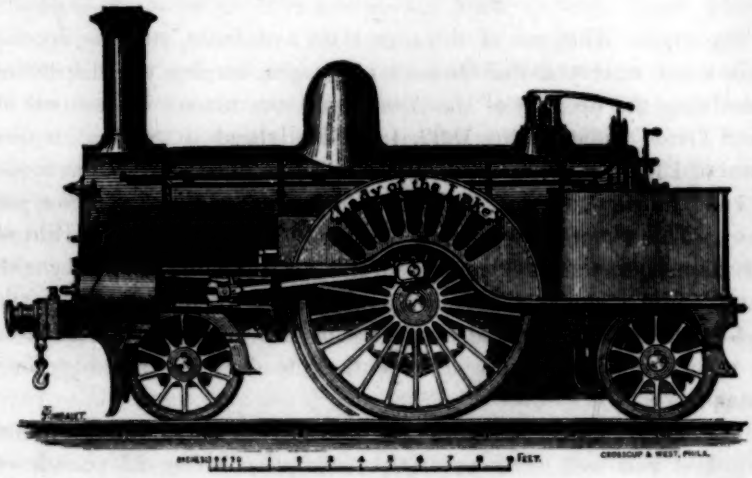
The Great Western Railway of England has seven feet gauge and was the fastest road in the world until a few years since, and its express ran regularly from Paddington (London) to Bristol, 118¼ miles, in precisely two hours, being at the rate of *fifty-nine miles* per hour.

The engines have 18-inch cylinders, 24-inch stroke, 8-feet driving wheels, and those of the largest size have 21 square feet of fire grate and a total heating surface of 1952 square feet. It has been said of them that they would evaporate from 500 to 360 cubic feet of water per hour, and are known to have worked up to quite 1000 indicated horse-power. At 60 miles an hour, 1000 horse-power would correspond to a mean effective pressure of 77·16 pounds per square inch upon the pistons (1851).

The difficulties so far for very large wheeled engines upon the narrow gauge are these: If the boiler is over the axle, the engine is top-heavy; if the boiler is beneath the axle of any pair of driving-wheels less than 12 feet in diameter, the form of the fire-box and disposal of the tubes are unsatisfactory, while, if the driving axle is behind the

fire-box (as in Norris Brothers' engines for the Camden and Amboy Railroad) hardly enough weight can be secured for adhesion. A large wheel, moreover, implies a large boiler, and not only is it difficult to provide room in a narrow-gauge engine for a very large boiler, but, beyond a certain size, there is a chance of failure under high pressures.

The following illustration represents the best average type of single express locomotives in general use on English railways for the last twenty years for the fast trains:



The above represents the "Lady of the Lake," the favorite pattern on the London and Northwestern Railway. This engine was exhibited at the International Exhibition in London, in 1862, and obtained a bronze metal for excellence of workmanship.

This engine was designed and constructed by Mr. John Ramsbottom. The following are its principal dimensions:

Area of grate in square feet, . .	14·9
Heating surface in " . .	1098.
Stroke of piston in inches, . .	24.
Diameter " " . .	10.
Diameter of driving wheels, . .	91·5
Length of wheel-base in feet, . .	15·5
Total weight of engine in working order in ton,	27·
" " tender " " "	17·5
" " engine and tender " "	44·5

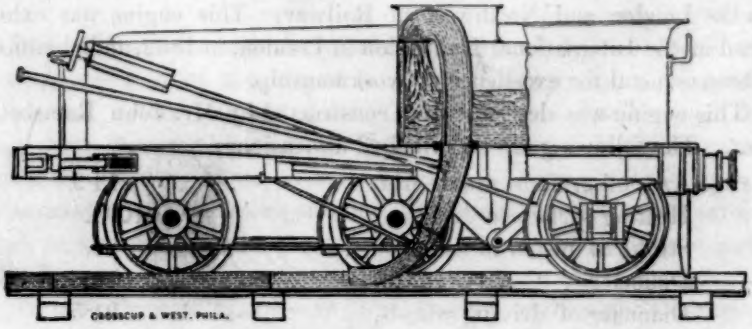
Weight on leading wheels of engine in pounds,			20,056·
"	driving wheels	" "	25,760.
"	trailing wheels	"	13,664·
Weight of engine empty		"	54,880·

The tractive force for each pound effective steam pressure per square inch on the piston this engine is capable of exerting will be

$$\frac{16^2 \times 24}{91{\cdot}5} = 67{\cdot}15 \text{ pounds.}$$

The engine *Watt*, one of the same class and build, run the special train which conveyed the Queen's messenger bearing the dispatches containing the decision of the American Government in the case of the "Trent" difficulty, in 1862, from Hollyhead to Stafford, a distance of 131 miles, without a single stoppage. The journey was made in 144 minutes, being at the rate of *fifty-four and a half miles per hour*. This remarkable run was made without stopping by the aid of Mr. Ramsbottom's "pick-up" apparatus for supplying the tender with water while running. This arrangement has been adopted by the Pennsylvania Railway, and by the use of which they have been able to reduce the size and weight of their tenders for running long distances.

The chief features of the above locomotives are that they steam well and run well, their average consumption being 22 pounds of Welsh coal per mile.



Tender "picking up" water from feed-trough when in motion.

The tender of the engine has six wheels, and weighs empty about 9½ tons; full, 17½ tons, and the load is equally distributed on the wheels.

The boilers of three engines evaporate from 150 to 180 cubic feet per hour, and in running long distances it was necessary to provide for filling the tenders with water when the train was in rapid motion. Mr. Ramsbottom conceived the idea of placing a pair of cast iron troughs, about 1500 feet long, on a level part of the road; each end about five feet had an incline of one inch in 100. The troughs are 18 inches wide and 7 inches deep, and are placed one between the rails of each line and so that the water, 5 inches deep, stands at about the level of the rails. The tenders are made to hold about 15,000 pounds, and are provided with a rising water pipe, the lower end of which is fitted with an adjustable scoop 10 inches wide at the mouth; as the scoop meets the water the effect is the same as if, the scoop being supposed at rest, the water were in motion at the velocity of the train. In either case the water must rise in the pipe, and, if permitted to do so, to a height the same as that from which a body falls, *in vacuo*, in acquiring the velocity with which the scoop and the water meet each other. At 32 feet per second, or, rather, less than 22 miles an hour, this height would be 16 feet. The height from the water trough to the top of the inlet pipe is 7½ feet, and a column of water of this height is just balanced, without delivery, at a speed of 15 miles an hour. The scoop dips two inches under the surface of the water, and at 22 miles an hour from 10,000 to 11,000 pounds are raised into the tender in 25 seconds. The delivery is practically the same at higher speeds, for although the velocity of the entering water is then greater, the time during which the apparatus is at work is diminished in the same proportion.

The Pennsylvania Railway have had a number erected on their different lines, and their advantages are, that the size and weight of the tender for running long distances may be reduced, the number of stoppages lessened and time saved. An express locomotive has thus been enabled to run the whole distance from New York to Pittsburg —438½ miles—in one continuous run of 10 hours and 5 minutes, at an average speed of *forty-three and one-half miles per hour.*

Advantage of Metallic Lubricants.—In a drying machine it was found impossible, even with the greatest care, to keep the arbors clean, so as to prevent the injury of the goods by grease-spots from the lubricating oil. The difficulty was entirely obviated by the use of *metaline* as a lubricant.—*Chron. Ind.* C.

AN ACCOUNT OF AN EXPERIMENT MADE TO DETERMINE THE POTENTIAL AND ECONOMIC VAPORIZATION OF A BOILER IN THE ESTABLISHMENT OF MR. FREMERY, AT EUPEN.

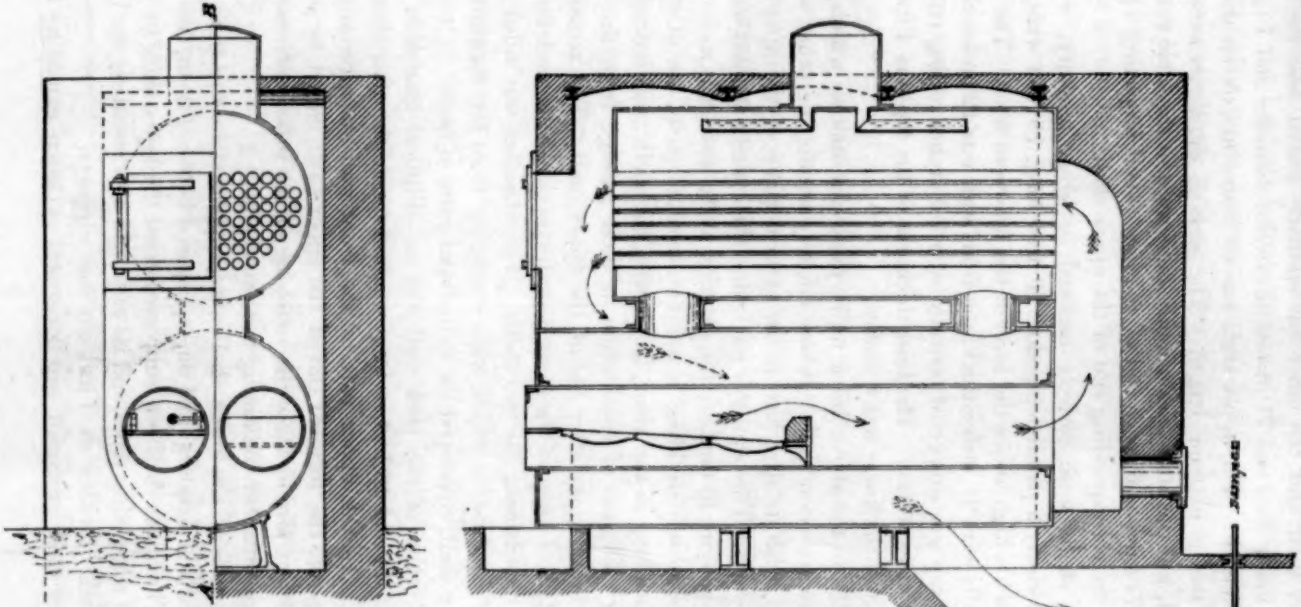
By Chief Engineer ISHERWOOD, United States Navy.

In the appendix to a report of the discussions which took place between the engineers-in-chief of various French and Belgian "Associations for the Surveillance of Steam Boilers," at a meeting held in Brussels on the 8th, 9th and 10th of July, 1877, there is given, among other information of engineering interest, a description of an experiment made by Mr. Vincotte, Engineer-in-chief of the Brussels Association, on the 27th of February, 1878, with a boiler belonging to the establishment of Mr. Frémery at Eupen. The object of the experiment was to determine the economic and potential vaporization in this boiler, of water, with average semi-bituminous coal, under the conditions of daily use.

As the boiler was of a type not employed in the United States, and had an unusual and excessively small proportion of draught area above the bridge walls, with an unusual and excessively large proportion of heating surface to grate surface, it seemed to the writer that the data and results of the experiment, arranged and reduced in the manner adopted by the engineers of English-speaking countries, would be of value to the readers of this JOURNAL. He has, therefore, recalculated all the quantities in English measures, and made from the French data the following account, taking nothing from the original except the observed quantities therein given, and adding his own remarks:

BOILER. (*See sketch*).

The boiler was composed of two horizontal cylindrical shells, one so placed immediately above the other that the same vertical plane passed through the longitudinal axis of each. The least space in the clear between the shells was 9 inches, and they communicated by two vertical pipes of $23\frac{5}{8}$ inches exterior diameter, whose vertical axes were also in the vertical plane passing through the longitudinal axes of the shells. One of these pipes was placed as near as practicable to the forward end



Half elevation. Half cross section. *Longitudinal section on A B.*

Boiler at Eupen experimented with by Mr Vincotte.

Scale 1 inch = 4 feet.

of the upper shell, and the other was similarly placed near the after end. The lower shell was 71 inches in exterior diameter and 15¼ feet in extreme length. The upper shell was 68 inches in exterior diameter and 13 feet in extreme length. The ends of the shells were flat and vertical, and the after ones of both shells were in the same vertical plane, the forward or furnace end of the lower shell projecting 2¼ feet forward of the corresponding end of the upper shell.

The two shells were entirely inclosed in brick masonry, which formed exteriorly a parallelopipedon 19 feet long, 10 feet wide, and 13 feet 4 inches high above the level of the fire-room floor. The back and side walls were 21 inches thick, the front wall was 12 inches thick, and the flat top was supported beneath by brick arches resting on iron beams of H cross-section. The least thickness of the top was 4 inches, and its greatest thickness was 8 inches.

In addition to the above brick walls, there was another which may be called the partition wall. It was entirely within the other walls, and vertical, with its after face in the vertical plane of the after ends of the two shells. This wall was six inches thick, and extended wholly across the inclosure formed by the exterior walls, and from its bottom to its top completely dividing it into two separate parts, one of which was 24 inches long in the clear, lengthwise the shells, and formed the channel for the gases of combustion in their passage from the after end of the lower to the after end of the upper shell. The remaining part was 12¾ feet long in the clear, lengthwise the shells, and formed the chamber containing the two shells. This chamber was filled with the gases of combustion which, after emerging from the forward end of the upper shell, enveloped the cylindrical parts of both.

At the bottom of the back wall was an elliptical man-hole with diameters of 14 and 18 inches, to give admission to the after chamber or channel. In the upper part of the front wall was a rectangular opening opposite the forward end of the upper shell, closed by doors, and of sufficient size to allow the sweeping of the tubes and entrance into the large chamber containing the two shells.

The two ends of the lower shell were supported on the front and partition walls of masonry, and on, equispaced between them, two iron castings. The upper shell was supported from the lower shell by their two vertical connecting pipes, and its after end also rested on the brick partition wall. Neither shell had any side supports.

The lower shell contained two horizontal cylinders extending from

one end of it to the other, and having their horizontal diameters in the plane of the horizontal diameter of the shell. These cylinders were 2·3622 feet in inside diameter and 15¼ feet in extreme length. In the forward portion of each cylinder, with a dead-plate 12 inches long between the forward end of the cylinder and the forward end of the grate, was placed a grate 6·5618 feet long, slightly inclining downwards toward the back. The bridge-wall was of fire-brick supported on an iron casting. The front end of the upper side of the grate was on a line with the horizontal diameter of the cylinder, and the back end was four inches below that line. The top of the bridge-wall was eight inches above the upper side of the grate at its back end.

The upper shell contained seventy horizontal wrought iron fire-tubes of 4 inches external and 3¾ inches internal diameter, with an extreme length of 13 feet. These tubes are arranged, vertically, in seven rows, the horizontal diameters of those of the third row from the top being in the plane of the horizontal diameter of the shell. In the top row there are ten tubes, in the next three rows twelve each, in the next row there are ten tubes, in the next row eight, and in the lowest row six. The least spaces between the tubes, both vertically and horizontally, are 0·8 inch in the clear. The tubes are placed vertically, one immediately over the other.

The normal water-level was 3 inches above the upper row of tubes, leaving 17 inches for the greatest height of steam room in the shell.

On the top of the upper shell and at the middle of its length was placed, vertically, a cylindrical steam-drum with a curved top. The exterior diameter of this drum was 2¾ feet and its extreme height above the top of the shell was 2½ feet. The steam from the shell was admitted to the drum through two perforated dry-pipes, which extended horizontally along the upper side of the shell. The steam-pipe connecting the boiler with the engine was bolted upon the top of the steam-drum.

The chamber enclosed by the brick masonry and containing the shells extended 16 inches deep below the lower side of the lower shell, and from this lower part, and at the back end of the shell, the gases of combustion were carried to the chimney through a horizontal flue of masonry lying beneath the floor of the boiler-house.

From the foregoing description it will be seen that the gases of combustion after crossing the bridge-walls in the lower shell, pass horizontally through the cylinders behind them into the channel or back

chamber of the masonry; thence they ascend vertically, enter the tubes in the upper shell, and, passing horizontally through them, debouche into the front chamber of the masonry, where they spread out and completely envelop both shells as they descend vertically to the bottom of the chamber and enter the horizontal brick flue which conducts them to the chimney. The direction of the gases is thus changed, first from horizontal to vertical, then from vertical to horizontal, and finally from horizontal to vertical, before they leave the heating surfaces; the distance they travel from the centre of the furnaces to the horizontal flue leading to the chimney is about 40 feet.

The surface of the steam room in the upper shell is steam superheating surface.

The following are the principal dimensions and proportions of the boiler, namely:

Extreme length of brickwork,	19 feet.
Extreme breadth of brickwork,	10 feet.
Extreme height of brickwork above bottom of chamber,	14½ feet.
Outer diameter of lower shell,	71 inches.
Extreme length of lower shell,	15¼ feet.
Outer diameter of upper shell,	68 inches.
Extreme length of upper shell,	13 feet.
Number of cylinders in lower shell,	2.
Inner diameter of cylinders in lower shell,	2·3622 feet.
Extreme length of cylinders in lower shell,	15¼ feet.
Number of furnaces,	2.
Breadth of grates,	2·3622 feet.
Length of grates,	6·5618 feet.
Aggregate area of grates,	31·0000 sq. ft.
Number of tubes in upper shell,	70.
Inner diameter of tubes,	3¾ inches.
Outer diameter of tubes,	4 inches.
Extreme length of tubes,	13 feet.
Aggregate cross area for draught through the tubes,	5·3689 sq. ft.
Aggregate cross area for draught over the bridge-walls,	2·8000 sq. ft.
Heating surface in furnaces to after side of bridge-walls,	63·1111 sq. ft.
Heating surface in cylinders beyond after side of bridge-walls,	107·6060 sq. ft.
Heating surface in back ends of the two shells,	28·1311 sq. ft.

Heating surface in the tubes, calculated for inside diameter,	893·3925 sq. ft.
Heating surface in the front end of the upper shell,	10·6387 sq. ft.
Heating surface in the cylindrical part of the upper shell,	141·6616 sq. ft.
Heating surface in the two pipes connecting the shells,	12·2500 sq. ft.
Heating surface in the cylindrical part of the lower shell,	249·4903 sq. ft.
Total water-heating surface in the boiler,	1506·2813 sq. ft.
Total steam superheating surface in the boiler,	75·8000 sq. ft.
Water-room in the boiler,	497·2077 cu. ft.
Steam-room in the boiler,	111·0882 cu. ft.
Square feet of water-heating surface per square foot of grate surface,	48·5897
Square feet of steam superheating surface per square foot of grate surface,	2·4451
Square feet of grate surface per square foot of draught area above bridge-walls,	11·0714
Square feet of grate surface per square foot of draught area through tubes,	5·7740

Coal.

The fuel consumed during the experiment was a good quality of semi-bituminous coal of the kind in daily use at the establishment, and it was burned just as received from the mine. A special analysis of this coal gave the following for its centesimal composition:

Hygrometric water,	1·084
Volatile matter other than water,	13·369
Coke, exclusive of ash,	76·965
Ash,	8·582
	100·000

Composition, exclusive of Hygrometric Water and Ash.

Carbon,	89·72
Hydrogen,	4·31
Oxygen,	4·20
Nitrogen,	1·00
Sulphur,	0·77
	100·00

Condition of the Boiler.

The sweeping of the boiler tubes, when in regular service, was done once in eight days. Three days before the date of the experiment they had been swept, so that they were in an average condition as regards soot. The other fire surfaces had not been swept for seven months, and must have been thickly coated with the soot due to the combustion of about 450 tons of coal in that time.

The water heating surfaces, on the water side, had not been cleaned for seven months, during which time about 3370 tons of water had been vaporized from them. This water, taken from the Vesdre river, was very pure and left no scale.

An analysis of the feed-water, previous to its entrance into the boiler, was made; and another analysis was made of the water in the boiler, which, as none of it had been blown out or removed, except by vaporization and foaming, for seven months, contained in solution nearly all the mineral matter entering with the water during that time, with the exception of what may have been precipitated as scale or sludge.

The following are the results of these two very interesting analyses, and show the centessimal composition of the waters:

	Feed-water when entering the boiler.	Feed-water in boiler after vaporization of 3370 tons.
Chloride of calcium,	0·019	1·765
Chloride of sodium,	0·005	1·766
Sulphate of soda,	0·005	0·855
Sulphate of lime,	.....	0·075
Alkaline nitrates,	traces	3·119
Organic matter,	0·025	2·170
Oxide of iron,	.....	traces
Magnesia,	.....	traces
Alumina, silica and loss,	0·001	0·010
Water,	999·945	990·240
	1000·000	1000·000

In comparing the above two analyses, there must be recollected: 1st. That the feed-water being very pure, some of the substances in solution, and notably the nitric acid, could not be determined with absolute precision. 2d. That the feed-water, as drawn from the river

Vesdre, necessarily varies slightly in composition from day to day; hence the single specimen whose analysis is first given in the above table may not, and probably does not, correspond exactly to the water whose analysis is last given, representing a mean of the feed-water during seven months. 3d. That a portion of the sulphuric acid and of the lime has disappeared to form scale and sludge. Notwithstanding the above uncertainties, these analyses are of much value from their rarity, and for the information they give in relation to the persistence of the chlorides of calcium and sodium, and of organic matter, in the fresh water of land boilers.

Experiment to ascertain the Potential and Economic Vaporization of Water by the Boiler with semi-bituminous Coal.

The experiment continued one working day of 13 consecutive hours, during which the quantity of water fed into the boiler was previously measured in a tank with great accuracy, the temperature being noted every half hour. The steam, as fast as generated, was worked off by the engine, the boiler pressure being maintained nearly uniform, and noted every half hour, also. The coal thrown into the furnaces, and the refuse therefrom, in ash, clinker, etc., were carefully weighed.

The fires, at the commencement, were started with just wood enough to light the coal, and at the end of the experiment they were burnt completely out, so that the weight of coal consumed was determined exactly. The water in the boiler at the commencement of the experiment had a less temperature than at its end, and there was, likewise, a slight variation in the quantity; these differences were carefully ascertained, and the weight of water vaporized, per tank, corrected for them.

As the day on which the experiment was made was a regular working day, intervening between two other working days, and as the fires were banked at night, the brick masonry was at about the average temperature at the commencement of the experiment, and did not require the expenditure of fuel to heat it up.

The coal was burnt at its maximum rate of combustion. The draught of the chimney was poor.

The following are the data and results of the experiment:

Boiler.	Square feet of grate surface per square foot of draught area over bridge-walls,	11·0714
	Square feet of water-heating surface per square foot of grate surface,	48·5897
Total Quantities.	Duration of the experiment in consecutive hours,	13·
	Total number of pounds of water vaporized from the mean temperature of the feed, namely 42 degrees Fahrenheit, under the mean steam pressure of 60¾ pounds per square inch above zero,	40398·
	Total number of pounds of semi-bituminous coal consumed,	5203·
	Total number of pounds of refuse from the coal, in ash, clinker, etc.,	617·
	Total number of pounds of combustible, or gasifiable portion of the coal consumed,	4586·
	Per centum of the coal in refuse,	11·859
Rate of Combustion.	Number of pounds of coal consumed per hour,	400·2300
	Number of pounds of combustible consumed per hour,	352·7700
	Pounds of coal consumed per hour per square foot of grate,	12·9106
	Pounds of combustible consumed per hour per square foot of grate,	11·3800
	Pounds of coal consumed per hour per square foot of heating surface,	0·2657
	Pounds of combustible consumed per hour per square foot of heating surface,	0·2342
Vaporization. *Absolute.*	Number of pounds of water that would have been vaporized had it been supplied at the temperature of 100 degrees Fahrenheit, and vaporized under the standard atmospheric pressure,	43501·7525
	Number of pounds of water that would have been vaporized had it been supplied at the temperature of 212 degrees Fahrenheit, and vaporized under the standard atmospheric pressure,	48584·5248
Economic.	Pounds of water vaporized from 100° Fahrenheit by one pound of coal,	8·3809
	Pounds of water vaporized from 100° Fahrenheit by one pound of combustible,	9·4858
	Pounds of water vaporized from 212° Fahrenheit by one pound of coal,	9·3378
	Pounds of water vaporized from 212° Fahrenheit by one pound of combustible,	10·5941

In the above experiment all the conditions were combined that should have given a maximum economic result. There was a very small calorimeter above the bridge-walls, whereby the air dilution of the gases of combustion was kept at a minimum. There was only a medium rate of combustion per square foot of grate per hour, and a very slow rate of combustion per square foot of heating-surface. The ratio of water-heating surface to grate surface was very large, and the direction of the gases of combustion in their route from furnace to chimney was several times changed, so as to thoroughly mix and com-

bine them. The coal was of excellent steam-producing quality. The experiment was of such short duration that, in connection with the small per centum of refuse from the coal, there could have been but little loss from the cleaning of fires; and the radiation from the thick walls of brick masonry must have been insignificant. Yet, notwithstanding all these favorable circumstances, the economic vaporization under the atmospheric pressure was only 10·5941 pounds of water from the temperature of 212 degrees Fahrenheit per pound of the combustible or gasifiable portion of the coal. This vaporization should have been not less than 12 pounds of water, which is what has been obtained in ordinary marine boilers during much longer experiments, with poorer proportions for economy of fuel, and not better coal, the rate of combustion per hour per square foot of heating surface being about the same. Here is a loss of economic effect of not less than $11\frac{3}{4}$ per centum, and to what is it to be attributed? Probably to the *infiltration of air through the masonry enclosing the boiler shells.* The comparatively cold external air so entering mixes with the hot gases of combustion and cools them by extracting a portion of their heat. The result is a less difference between the temperature of the mixture and that of the boiler water than would have been between the latter and the gases of combustion if unmixed, accompanied by a correspondingly less extraction of heat in equal time. Another injurious result is that the cool infiltered air, after absorbing heat from the gases of combustion, passes out with them at the same chimney temperature; the loss of heat thus caused being measured by the weight of air entering, its specific heat, and the difference of its temperature when entering and leaving the boiler. The cooling effect of the infiltering air may even check the combustion of any uncombined coal gases in the tubes and connections.

The greater the rate of combustion in a boiler set in masonry the greater will be the *absolute* quantity of air inleaked, because the greater rate of combustion is necessarily associated with a less pressure inside the masonry, that of the external air remaining constant. In fact, it is this less pressure which gives the greater draught, producing the greater rate of combustion. But, as this greater rate of combustion causes a correspondingly greater quantity of hot gases to pass through the masonry flues in equal times, the per centum of loss by the inleaked air, that is, the loss *relative* to the absolute quantity of heat in the hot

gases, will not be materially changed by change in the rate of combustion, within the limits of ordinary practice.

During the many experiments on boiler vaporization made or investigated by the writer an inferior result was always found with boilers of the same type, having the same proportions of heating to grate surface, and of calorimeter; burning the same coal at the same rate of combustion per hour per square foot of grate surface; but having their furnaces and flues in brick masonry instead of in iron shells; and just in proportion to the extent of the brick surface with which the gases of combustion were in contact.

Whenever the highest vaporization is desired from the fuel consumed at a given rate of combustion, brick settings should be wholly discarded and all parts of the boiler arranged within an iron shell; and the difference will be the greater with boilers having the least ratio of water-heating to grate surface, because in them the gases of combustion enter the chimney with the highest temperature, and the infiltered air carries off a correspondingly greater quantity of heat. Were it possible for the gases of combustion to leave the boiler with the temperature of the atmosphere, there could, of course, be no economic loss by any amount of air leaked in, for whatever heat was imparted to it on entering would be yielded up before leaving; the loss will be just in proportion to the temperature of the chimney, other things equal.

When it is considered that walls of brick masonry are easily pervious to water, there can be no difficulty in believing they are still more easily permeable by air. If brick-work be adopted for the setting of boilers, an air space of about 2 inches width should be left in the masonry, whose entire exterior should be well coated with pitch, or with a cement of mastic, to stop the inleakage of air as much as possible. This, however, the writer has never known done; and he has always observed that, after a short period of use, the masonry was more or less warped by heat, and cracked, the inleakage of air becoming correspondingly increased.

When a boiler set in brick-work is used during only a portion of the day, as is generally the case, a serious loss of fuel is experienced in heating the mass of masonry from the temperature it has when the boiler is out of use to its temperature when the boiler is in operation. This loss is measured by the weight of the masonry into the product of its specific heat by the difference of the temperatures stated.

A boiler set in brick-work will also lose more heat by radiation

than one whose gases of combustion are wholly within its shell, because the first will have a greater external surface than the second, and because the temperature of the gases of combustion are on one side of the setting, while in the case of the second the temperature in contact with the felt or other covering is only that of the contained steam, or about half as much. In either case, however, the loss by external radiation of heat is comparatively trifling.

During the experiments repeated tests were made of the steam, in order to ascertain if it carried over any water in suspension, and, if so, how much. The various methods gave reasonably accordant results, and showed that no more than $\frac{1}{328}$ of the water in the boiler was so entrained. This quantity is not deducted from the vaporization given in the preceding table, because it was desired to have that vaporization comparable with the results of other similar experiments, and because there is great doubt of the accuracy of such determinations, which are really among the most delicate, complex and difficult in physical science, while the methods practically adopted are so very crude as not to be even approximately reliable. The proportion of water foamed over, or entrained in boilers, has been, in consequence, absurdly exaggerated.

Finally, there may be remarked that the hygrometric moisture in coal will, in general, about offset the water that may be carried over from the boiler by foaming, so that the apparent vaporization, including the entrained or foamed over water, will be about the true vaporization, exclusive of the entrained water given by the coal, exclusive of its hygrometric water.

Magnetic and Diamagnetic Elements.—The magnetic elements are N, O, Fe, Ni, Co, Mn, Pt, Os, Pd, Ir, Rh, Cr, Ti, Ce, C, K and U. The diamagnetic are H, Na, Cu, Ag, Au, Hg, Zn, Cd, Pb, Sn, P, As, Sb, Bi, S., Se, Cl, Br, I, Ti, Si. Carnelly has observed that all the elements which are found in the even series, in Mendelejeff's classification, are magnetic, while those of the odd series are diamagnetic. This result furnishes new and interesting evidence of the shrewdness of the investigators who are endeavoring to trace all chemical and physical phenomena to the action of primitive laws of motion. *Ber. d. D. Chem. Gesell.* C.

PROGRESS OF THE DEPHOSPHORIZATION OF IRON.

By F. GAUTIER.

Read before the Society of Civil Engineers of Paris, January 9th, 1880.
Translated by CHAS. E. BILLIN.

In my communication of July 4th, 1879,* I endeavored to show the state in which this very important question was at that time. The result of that study was that two processes were shown to have arrived at results of a certain value: the *Thomas-Gilchrist process*, by which Bessemer steel can be obtained from a pig iron as highly charged with phosphorus as the iron of Cleveland and the Moselle, and the *Krupp* or *Narjes-Bender process*, producing purified pig iron (*fontes mazée*), partially dephosphorized, and capable of being used in puddling or in the Martins-Siemens furnace.

The *Thomas-Gilchrist process*, as it has been explained in numerous communications read before the Iron and Steel Institute, at its meeting in London, and by public experiments at Eston near Middleboro', in the works of Messrs. Bolckow and Vaughan, presented the following characteristics:

Employment of a dolomitic casing, replacing the old-styled silicious lining of the converters.

Addition, at the commencement of the operation, of a mixture of lime and oxide of iron, intended to absorb the silica and phosphoric acid produced.

Continuation of the blowing beyond the ordinary stopping point in Bessemer operations.

Determination of the practical end of the dephosphorisation by a series of samples and repeated trials.

Under these conditions steel very low in carbon and containing no more than 0·15 of phosphorus has been produced from pig iron carrying 0·15; but in operating in this manner there are numerous causes of cooling. To avoid *projections* only a small charge was treated in a large converter, which augmented the loss by radiation. The addition of the oxide of iron was also a notable element in lowering the tem-

* See the JOURNAL for February, 1880, p. 83.

perature of the operation; finally, the repeated tests at the close necessitated the loss of precious time.

In order to obviate these inconveniences, they have treated iron carrying as much as 3 per cent. of silica, the calorific power of which is very high. But this only places the problem in a deceptive circle. It is necessary to increase the basic additions in order to absorb the great quantity of silica thus produced, for there cannot be left more than 20 per cent. of silica in the slag without endangering the stability of the phosphates formed.

At the moment of the recarburation this very fluid slag, is moreover, traversed by the carbonic oxide resulting from the reaction of the carbon of the spiegel on the oxide of iron of the bath. There is then produced a partial rephosphorization of the purified metal; about a thousandth of phosphorus is added to that which had been left in the steel, and probably can only proceed from the action of the manganese of the spiegel, or of the carbonic oxide, on the phosphates of the slag. These reactions, moreover, whatever their nature, are produced with violence; the final addition should be made in several portions to avoid a sudden projection of the slag out of the converter. The metal obtained remained cold; the loss was as much as 18 to 20 per cent., that is to say, it required 1200 kilogrammes of metal, from the furnace, to obtain 1000 kilogrammes of steel ingots, whereas 1130 or 1140 suffice when the metal is pure and is submitted to ordinary treatment by the Bessemer process. The refuse from rolling attained 10 per cent. in the month of May last, and seldom was lower than 5 per cent.

Progress in England.—The first question which occupied the English engineers was to reduce the basic addition, the absorbing capacity of which was complicated with a very marked cooling action. They suppressed the oxide of iron, and forced in the limestone by an artifice analogous to that used at Neuberg in the treatment of white and mottled iron by the Bessemer process, where charcoal dust was introduced with the blast. They succeeded thus in eliminating half the phosphorus, at the same time retaining 2·5 per cent. of carbon, whereas in the old way of operating, when the carbon was reduced from 3·5 to 2·5 the diminution in the phosphorus was seldom more than 5 or 6 per cent. The suppression of the oxide of iron diminished the cooling, and protected the lining, the slag being less corrosive; but at the same time it produced obstructions at the mouth of the converter, and, to

remedy this they modified the form of the latter. They supplanted the lower demi-sphere by a right cone, decidedly truncated; the gases were then freely disengaged, and projections tumbled back into the bath without encumbering the throat.

To prevent the final explosions which resulted, as we have said, from the too quick reaction of the oxide of iron of the bath on the carbon of the spiegel or of the ferro-manganese, they called to their aid silicon. In acting on the dissolved oxide the silicon gives origin to silica, which remains in the bath and has no tendency to be projected outside.

$$3Fe^3O^4+Si=9FeO+SiO^3$$

If the silicon finds itself in presence of carbonic oxide, formed by the inevitable action which the carbon accompanying it exercises on the oxide of iron of the bath,

$$Fe^3O^4+C=3FeO+CO$$

the silicon decomposes this gas, giving origin to silica and to a deposit of carbon, which is redissolved in the metal

$$Si+3CO=3C+SiO^3$$

It will be remembered that it is this reaction which explains the formation of steel without blowholes by means of silicon.

This addition of silicon was made at Eston under the form of grey pig carrying 3 per cent. of silicon. In conformity with the preceding theory, the disengagement of carbonic oxide, which gave to the operation of overblowing a dangerous character, was entirely removed; the subsequent addition of the spiegel, destined to remove by the manganese the last traces of "red shortness," and to communicate to the metal the proper degree of carburation, was made with quiet and precision.

In order to simplify, it has been proposed in France to employ silicide of iron and manganese, which ought to have several important advantages. First, it reduces the additions to one only; and, further, in these alloys, high in silicon, the carbon is in very small proportion, not often passing 1·5 per cent., the chance of the production of carbonic oxide is reduced to a minimum; finally, the simultaneous presence of manganese and silicon ought, under an oxidizing action, to lead to the production of a very fusible silicate of iron and of manganese, and in consequence to give great homogeneity to the metal.

The trial of silicate of iron and of manganese was not made in England, except under imperfect conditions; the alloy carried but 3 per

cent. of silicon, and did not permit obtaining all the effect which one might expect.

It will be remembered that the experiments at Eston had led to the noting of a singular phenomenon: the metal dephosphorized to 0·140 was suddenly changed to 0·235 of phosphorus after the addition of the spiegel. As the spiegel contained both carbon and manganese, it is to the presence of one or the other of these substances, and to their action on the phosphate of the slag, that we must attribute this rephosphorization, which sometimes exceeded one-thousandth. The silicon, in combatting with the carbonic oxide, prevented the rephosphorization. This would seem to give reason to the opinion attributing this augmentation of phosphorus to the action of the carbonic acid on the slag.

Another means to avoid the rephosphorization was also tried at Eston. The mass of metal and slag was cooled in a ladle furnished with a stopper and an orifice at the bottom; then the metal alone was led into a second ladle, where, protected from the contact of the slag, the introduction of the spiegel was made.

This arrangement succeeded well enough, but it was renounced, owing to the additional cooling which resulted from it, and which it was easy to foresee.

Finally, in order to comply with certain criticisms expressed in regard to the accuracy of the diagrams representing the relative oxidation of the different elements which accompany the iron in the metal treated, Mr. Richards submitted to the meeting of the Iron and Steel Institute, at Liverpool, the results of samples taken every three minutes after the commencement of the operation.

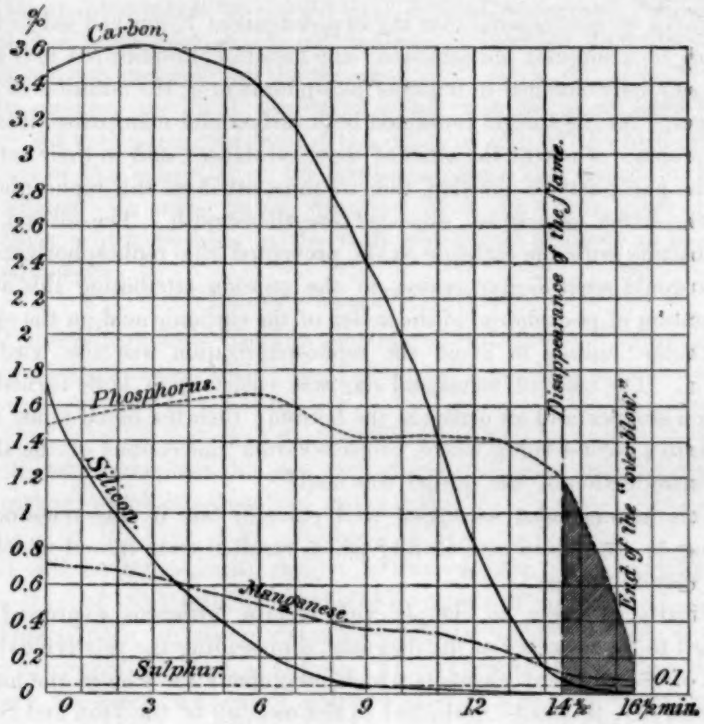
Metal.

Time,	0	3′	6′	9′	12′	14′ 30″	16′ 30″
Phosphorus,	1·5	1·6	1·63	1·43	1·42	1·2	0·08
Carbon,	3·5	3·6	3·4	2·4	0·9	0·075	.....
Silicon,	1·7	0·8	0·28	0·05	0·01	0	0
Manganese,	0·7	0·62	0·55	0·37	0·28	0·13	0·1
Sulphur,	0·05	0·05	0·05	0·05	0·05	0·05	0·05

Corresponding Slags.

Time,	3′	6′	9′	12′	14′ 30″	16′ 30″	16′ 35″
Silica,	32·60	42·60	36·00	35·60	33·00	15·60	16·60
Phosphoric acid,	0·60	0·15	1·60	2·61	5·66	15·06	16·03
Iron,	5·65	2·	4·60	4·80	6.15	10·45	11·35

The following diagram shows these results graphically.



En résumé, the improvements introduced in England do not modify the nature of the first material employed. This always remains a very gray and silicious iron, comparatively difficult and costly to produce.

Progress in Westphalia.—The most important modifications introduced in the working of the Thomas-Gilchrist process reach us from the works of Hörde. The director, M. Massenez, and the engineer, M. Pink, have given, at the matallurgical meeting at Dusseldorff (General-Versammlung des technischen Vereins für Eisenhüttenwesen), held December 15th, 1879, very detailed descriptions, which we have every reason to believe exact.

Dephosphorization was attempted September 22d, 1879, and from the first, M. Massenez (to give his own figurative language) "declared an obstinate war to the silicon, in order to make a compact of friendship with the phosphorus."

He asserts that with "white" iron, having 0·5 of silicon, 2·5 of carbon, and more than 2·0 of phosphorus, to have succeeded in making steel having ·03 to ·06 of phosphorus.

Below are given some numerical details communicated by the works of Hörde:

	Horde Iron.		Luxembourg Iron.
	Grey.	White.	
Silicon, . .	1·50 to 2·85	0·36	1·218
Phosphorus, .	1·30 to 1·01	1·70	1·726
Sulphur, . .	0·01 to 0·07	0·16	0·173
Manganese, .	1·30 to 0·65	1·30	0·497
Carbon, . .	3·60 to 3·34	2·30	3·122

Operation No. 67.

Grey iron of Hörde, . . .	1200 kil.
White iron " . . .	1500 "
Steel scrap, . . .	500 "
Spiegel, . . .	210 "
	3410
Yield, . . .	3087

	Phosphorus.	Carbon.	Sulphur.	Manganese.	Silicon.
Pig iron, . .	1·04	2·58	0·22	1·35	1·08
After 11′ 45″, .	0·82	0·08	0·19	0·39	0·09
After 100″ of overblowing,	0·08	0·06	0·15	0·39	0·007
15″ later, . .	0·045	0·04	0·14	0·37	0·005
Final product, .	0·06	0·28	0·067	0·46	0·002

Operation No. 68.

Grey iron of Hörde, . . .	1200 kil.
White iron, . . .	1500 "
Scraps, ...	600 "
Spiegel, . . .	210 "
	3510 "
Yield, . . .	3126 "

	Phosphorus.	Carbon.	Sulphur.	Manganese.	Silicon.
Pig iron,	0·96	2·82	0·16	1·04	0·45
After 14′,	0·70	0·09	0·16	0·40	0·02
After 110″ of overblowing,	0·09	0·085	0·15	0·33	0·003
15″ later,	0·05	0·081	0·09	0·29	.....
Final product,	0·06	0·26	0·009	0·31	.....

Operation No. 69.

Grey iron,	900 kil.
White iron,	1800 "
Scraps,	600 "
Spiegel,	210 "
	3510 "
Yield,	3156 "

	Phosphorus.	Carbon.	Sulphur.	Manganese.	Silicon.
Pig iron,	1·04	0·73	0·25	1·27	0·72
After 12′,	0·74	0·08	0·18	0·45	0·14
After 120″ of overblowing,	0·06	0·07	0·12	0·19	0·004
Final product,	0·06	0·24	0·063	0·40	.....

The total of these three consecutive runs gives:

Material treated,	10·430	1·120
Yield,	9·310	1·000
Loss,	1·120	·120

The total weight of the slag would be 2250 kilogrammes.

Final Slags.

	(*a*).	(*b*).	(*c*).
Silica,	9·50	13·81	11·10
Phosphoric acid,	9·76	7·38	12·43
Magnetic oxide, Fe^3O^4,	9·28	6·92	11·25
Protoxide of iron,	.....	1·41	.....
Protoxide of manganese,	6·16	6·20	4·40
Lime,	59·35	57·85	50·21
Magnesia,	5·01	6·93	9·84
Sulphuret of calcium,	0·87	0·22	1·15
Alumina,	traces	traces	traces
Totals,	99·93	100·72	100·38

The slags (*a*) and (*b*) belong to several operations; the analysis (*c*) is the average from the three operations, 67, 68 and 69.

The fact of there being only traces of alumina should be noticed. Before this, at Eston, with bricks containing 10 per cent. of alumina, there was only found 1·3 per cent. in the slag; it seems, then, that the alumina has less tendency than the lime and magnesia to be attacked under the double action of the silica and phosphoric acid.

The metal, tried for tensile strength, gave:

	Breaking load in kilogrammes per millim. sq.	Elongation. Per cent.	Contraction. Per cent.
Operation No. 67, .	50·1	20·6	44·8
" 68, .	53·5	22·0	47·0
" 69, .	54·3	19·2	42·0

The length of the test pieces is not indicated.

At Hörde they have also made metal for sheets, giving 39 kilogrammes of resistance per millimetre square, and 70 per cent. of contraction.

It is to be regretted that the figures relative to still more phosphoric runs have not been communicated.

That which characterizes these very interesting experiments is the substitution of phosphorus for the silicon, as the calorific element in the Bessemer process. Until the present we only knew two elements, the combustion of which could develop and maintain the temperature necessary to the operation—*silicon* and *manganese*—the first having a calorific power of 7830, according to recent researches of Troost and Hautefeuille, and the second of 8000, according to the same authors. The engineers of Hörde present to us a third substance—*phosphorus*—the combustion of which will be, under equal pressure, an element of heat at least as intense as silicon or manganese. According to Laplace and Lavoisier, the calorific power of phosphorus, in changing to phosphoric acid, would be 7500 calories, and if we compare the products of the combustion, phosphoric acid, on the one part, silica, oxide of manganese, on the other, leaving to the contact of the bath all the heat produced, we will no longer be astonished at this new role played by the phosphorus.

They even assert that the works of Hörde have specified, in buying pig iron for Bessemer use, that it shall contain at least 2 per cent. of phosphorus, not more than 1 per cent. of silica, nor 0·2 of sulphur.

They also speak of the manufacture of special alloys of iron and phosphorus destined to introduce the quantity of this last substance necessary to the operation (M. Gautier presented to the meeting specimens of phosphuret of iron containing 22 per cent. of phosphorus. It is silver white, iridescent upon fracture, and very difficult to attack with acids).

The substitution of phosphorus for the silicon has the effect of making the phosphates predominate in the slag; these are much less corrosive than the silicates, and the wear and tear of the lining is less.

The operation at Hörde is conducted in a manner notably different from that which we have seen in the works of Bolckow-Vaughan.

As soon as a charge is finished they put in the converter the addition of lime for the next charge, about 20 per cent. of the weight of the iron to be treated. They add coke and coal, in large pieces, raise the converter and blow. The hydrate of lime is decomposed, and the last traces of carbonic oxide are expelled. They thus diminish the projections and partial explosions, which were frequent with the old method of working, and overcome in part the cooling which accompanied the cold additions made at the commencement. It is not until later that they charge the pig metal.

On account of the feeble amount of silicon which the iron contains, and probably, also, owing to the presence of a small amount of coke from the preliminary heating, one perceives immediately the yellow ray of sodium, and the spectrum is not long in expanding.

The operation is notably shortened, and lasts from 8 to 15 minutes at most. Observation shows that the oxidation of the phosphorus does not commence until after the elimination of the greater part of the silicon, and after the combustion of a considerable proportion of carbon. Nevertheless, the dephosphorization was more rapid than at Eston, and there is also no need for continuing the overblowing for as long a time. It varied between 100 and 240 seconds; but ordinarily 100 to 150 seconds suffices. When the nature of the metal to be treated is known in advance, the operation can be governed by the length of time after the disappearance of the spectrum and the cessation of the flame. A small ingot is then taken by means of a ladle which is plunged into the converter. This is hammered, cooled and broken. The appearance of the break is sufficiently characteristic to indicate the increase (of phosphorus?) given by overblowing. The engineers of Hörde claim to find in the aspect of the fumes an evi-

dence of the practical end of dephosphorization. When there is, so to speak, no more phosphorus, the oxygen of the air exerts itself entirely on the iron and manganese, and there are then seen abundant fumes of a very peculiar intensity, proceeding from the oxides of iron and manganese. There were no projections during the operation, which is surprising for nearly white iron. It is necessary, from this point of view, to believe that the phosphorus acts in the same protective way as the silicon, and prevents the reaction of the oxide of iron on the carbon from becoming tooviolent.

The operation is terminated by the addition of spiegel. Neither explosions nor rephosphorization of the dephosphorized metal are noticed. There is something here which demands an explanation, for the engineers of Hörde do not seem to have recourse to silicious additions, and one cannot well see how the carbon of the spiegel would react less tumultuously here, on the oxide of iron of the bath, because the pig iron was less silicious and contained more phosphorus.

The lining, of which we have not yet spoken, for it presents no new character, is made with dolomitic bricks, having the following composition:

	Before baking.	After baking.
Silica, . . .	2·14	9·43
Iron and alumina, .	0·62	4·13
Carbonate of lime, . .	55·05	.....
Carbonate of magnesia, .	42·50	.....

These bricks, like those which they used at Eston, are long and difficult to bake. 36 hours for kindling, an excessively quick fire during 100 hours, and slow cooling of 100 hours, are necessary. The dolomite of Rühr, which they employ, is neither rare nor costly, but 5 tons of coal are necessary to bake 1 ton of bricks.

These basic linings resist for a hundred operations; this is already a splendid result; but the converters, with ordinary silicious lining, support a thousand operations before requiring renewal, which is generally caused more by accumulations than by corrosion.

The bottoms are made (en pisé) with the débris of basic bricks, agglomerated with mineral pitch. They employ no tuyeres, but pierce holes in the mass, which are necessary for the introduction of the air. These bottoms will resist fifteen operations, about half the life of ordinary silicious bottoms. Their deterioration would seem to be due more to a physical action than to a chemical decomposition. Perhaps,

in increasing the blast pressure, the shocks from the liquid mass would be diminished and agitations quieted, as has been observed in Sweden.

The loss, according to the engineers of Hörde, is not greater than in their ordinary operations with pig iron from hematites, 10 to 11 per cent.; whereas with the silicious iron of Luxemburg, in the same basic converters, the loss reached 15 per cent. M. Massenez gives the following explanation: 1 part of silicon requires at least 2 parts of iron to form a silicate; the less silicon there is to scorify, the less will be the loss of iron.

This seems probable, for it has been long noticed that silicious iron leads to a greater loss in puddling. Further, the phosphoric acid, the state of which in the slag is a subject of much dispute, combines, in part at least, with the lime and magnesia, and is not so greedy for iron as the silica.

The sulphur of the iron seems to be eliminated to two-thirds. What becomes of it? It is held that the manganese facilitates desulphurization. It is necessary to admit, then, that it forms some sulphuret of manganese or of calcium in solution in the slag, a point which is not yet elucidated, and which presents great importance in the future of the process; for, if it is easier and more economical to produce "white" iron, it is to be feared, also, that it is much less sulphurous than grey and silicious iron obtained from the same burden.

The fact that phosphorus is sought for in the iron, or added during the operation, as the case may be, in order to facilitate its after elimination, is certainly very interesting, and seems even paradoxical.

(To be continued.)

American Laureates of the French Academy.—At the last public annual session of the French Academy the Lalande prize was awarded to Prof. C. F. H. Peters, of Clinton, N. Y., for his planetary discoveries. The total number of asteroids discovered by him is 43, eight of which were added to the list during the past year. At the the same sitting, the Valz prize was awarded to M. Trouvelot, of Cambridge, Mass., whose magnificent drawings of the planets Mars, Jupiter and Saturn represent the telescopic appearances with remarkable accuracy and furnish an excellent basis for the minute study of the superficial phenomena of these planets.—*Comptes Rendus.* C.

THE INVOLUTE OF THE CIRCUMFERENCE OF A CIRCLE.

By L. D'AURIA.

Professor of Applied Mechanics, former Engineer of the Military Topographic Institute in Italy, etc.

The relation between the circumference of a circle and its involute, as well as the relation between the area of a circle and the area generated by the tangent line in describing the involute of the same circle, once occurred to the writer in a problem of mechanics, and fruitlessly he searched in many authors of differential and integral calculus in use to find them; so that he was compelled to determine these relations by himself. The following is the method he used:

Let L be the length of the involute of an arc of circle of radius R, and φ degrees. If we imagine the circular arc divided in a certain number, n, of equal parts, each part will evidently contain $\frac{\varphi}{n}$ degrees; and if we imagine drawn the tangent lines at the extremities of these n arcs of circle, the angle formed by two consecutive tangents will be also $\frac{\varphi}{n}$ degrees.

Now, the length of one of the n circular arcs is

$$\frac{\pi\,\varphi\,R}{180.n};$$

and the length of the successive tangent lines drawn at the extremities of the n circular arcs, and confined between the involute and the evolute, are evidently

$$0,\ \frac{\pi\,\varphi\,R}{180.n},\ \frac{2\pi\varphi R}{180.n},\ \frac{3\pi\varphi R}{180.n},\ \ldots\ldots\ \frac{n\pi\varphi R}{180.n} \qquad (1)$$

When n is a very great number, the sum of the n successive arcs of involute confined between the $n+1$ tangents (1), will be equal with approximation to the sum of n circular arcs, each containing $\frac{\varphi}{n}$ degrees described successively by radii equal to the tangents (1).

The sum of these n circular arcs is

$$\frac{\pi^2\varphi^2 R}{180^2.n^2} + \frac{2\pi^2\varphi^2 R}{180^2.n^2} + \frac{3\pi^2\varphi^2 R}{180^2.n^2} + \ldots + \frac{n\pi^2\varphi^2 R}{180^2.n^2};$$

therefore approximately will be

$$L = \frac{\pi^2\varphi^2 R}{180^2.n^2}(1+2+3+\ldots+n) = \frac{\pi^2\varphi^2 R}{180^2.n^2} \times \frac{n(n+1)}{2}; \text{ or}$$

$$L = \frac{\pi^2\varphi^2 R}{2.180^2}\left(1+\frac{1}{n}\right).$$

This formula, with the supposition of $n = \infty$, becomes exact, and will be

$$L = \frac{\pi^2\varphi^2 R}{2.180^2}. \qquad (2)$$

When $\varphi = 360°$

$$L = 2\pi^2 R;$$

or denoting by C the circumference of the circle (evolute)

$$L = \pi C. \qquad (3)$$

The formula (2) holds good, also, when the involute of the whole circumference being described by a thread developing from it, this operation is continued, so that the rotation of the tangent line will exceed 360°.

Substituting in equation (2) successively

$$\varphi = 360,\ \varphi = 2 \times 369,\ \varphi = 3 \times 360,\ \ldots\ \varphi = N \times 360,$$

the corresponding values of L will be

$$\pi C,\ 3\pi C,\ 5\pi C,\ 7\pi C,\ \ldots\ (2N-1)\pi C.$$

These values form a series proportional to the series of the odd natural numbers 1, 3, 5, 7, 9, 11, ...

Denoting by A the area generated by the tangent line in describing the involute of a circular arc of radius R and φ degrees, conserving the other denotations (n being a very great number) the area A will be, with approximation, equal to the sum of n circular sectors, each containing $\frac{\varphi}{n}$ degrees, described successively by radii equal to the tangents (1). This sum is

$$\frac{\pi^3\varphi^3 R^2}{2\cdot 180^3\cdot n^3} + \frac{2^2\cdot\pi^3\varphi^3 R^2}{2\cdot 180^3\cdot n^3} + \frac{3^2\cdot\pi^3\varphi^3 R^2}{2\cdot 180^3\cdot n^3} + \ldots + \frac{n^2\pi^3\varphi^3 R^2}{2\cdot 180^3\cdot n^3};$$

therefore with approximation will be

$$A = \frac{\pi^3\varphi^3 R^2}{2\cdot 180^3 n^3}(1^2+2^2+3^2+\ldots+n^2) = \frac{\pi^3\varphi^3 R^2}{2\cdot 180^3 n^3}\left(\frac{n^3}{3}+\frac{n^2}{2}+\frac{n}{6}\right)$$

$$\therefore \qquad A = \frac{\pi^3 \varphi^3 R^2}{2 \cdot 180^3} \left(\frac{1}{3} + \frac{1}{2n} + \frac{1}{6n^2} \right)$$

This formula, with supposition of $n = \infty$ becomes exact, and will be

$$A = \frac{\pi^3 \varphi^3 R^2}{6 \cdot 180^3}$$

When $\varphi = 360°$

$$A = \frac{4}{3} \pi^3 R^2 ; \text{ or } A = \frac{1}{3} \pi \cdot C^2.$$

This last formula and formula (3) can easily be memorized, and although they are not in use in ordinary problems of mechanics, it would be not superfluous to introduce them in some manual of engineering.

A NEW PENDULUM SUSPENSION.

By Louis H. Spellier.

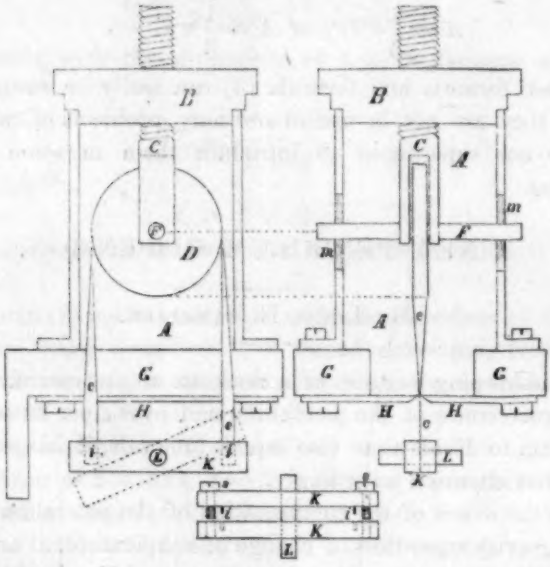
The time-keeping qualities of a clock are almost entirely dependent upon the correctness of the pendulum, and ever since its introduction as a medium to divide time into equal intervals, it has received the very greatest attention accordingly.

As it is the object of the compensation of the pendulum to keep its centre of gravity regardless of change of temperature, at an equal distance from its centre of oscillation, so its suspension should allow only its re-occurring oscillations to follow the track of a straight line and to move in a straight plane only.

The chief if not the only condition to arrive at this result is to give the suspending spring an even tension. Unless this condition is complied with the oscillating pendulum will be accompanied by the well known wabbling side motions which so greatly interfere with its correctness.

Pendulums have been suspended on one as well as on two springs, the latter of which is almost entirely abandoned. None of the suspensions so far had a contrivance which would automatically adjust the tension of the suspending spring, and so with mathematical certainty avoid the wabbling motion alluded to. The author claims to have succeeded in constructing such a suspension. It solves the problem perfectly.

A is a tube screwed on to the supporting base *G*. *B* is a round piece covering and fitting into the tube *A*. Through the centre of *B* goes a screw-threaded spindle *C*, which bears on its lower end, between a fork-like cut, a pulley *D*. *F* is the pin on which the pulley turns and extends through opposite cuts in the tube, to prevent *C* and *D* from turning when *B* is turned to lower or raise the pulley *D*.



Over the pulley the suspending spring *e* lies, and its two ends are fastened between the two bars *KK*. The two plates *HH* are screwed against the under part of *G*, and just far enough apart to allow the ends of the spring to extend laterally through the slit they form.

If now the pendulum hangs on the *L* its weight will bear equally on either side of the spring by means of the pulley, and adjust its tension automatically.

How perfectly that suspension adjusts the tension can be seen if we bring the bars *KK* into the position shown by the dotted lines. Even this abnormal position will not interfere with the pendulum in performing its oscillations in a true plane. While with other suspensions it would be impossible to avoid the wabbling motions if *K* and *H* would vary the least from being parallel.

THE PUDDLING PROCESS, PAST AND PRESENT.

By Percival Roberts, Jr.

Read before the American Institute of Mining Engineers.

It may seem necessary to offer an apology for presenting for consideration a process which is conspicuous by its absence in the literature of the Institute, and which may be thought by some to belong to the past in metallurgy, and to have been already superseded. But the large capital invested in puddling calls for a careful consideration of the question whether the time has certainly arrived when the puddling furnace must be replaced by the converter and open-hearth furnace. May there not still be a place for puddled iron alongside of molten iron and steel, and is not the improvement of the puddling process itself worthy the attention of engineers equally with the Bessemer and open-hearth processes?

The changes involved in the conversion of pig iron into wrought iron are well understood and need only be briefly alluded to. The patent of Henry Cort bears the date of 1784. Since that time the improvements in the process have mainly consisted in the replacement of sand by iron bottoms by Samuel Baldwyn Rogers in 1818, and the still more recent substitution of iron oxide for the refractory materials used for the sides and bridge of the hearth, which distinguishes the wet or boiling process from the dry or puddling process. Chemically, the process consists in the removal of the metalloids from the pig iron, a result effected mainly by the iron oxide. Silicon is first oxidized, then the phosphorus, and finally the carbon. The silicic and phosphoric acids produced pass into the cinder and the carbonic oxide burns as it escapes from the bath of metal.

It ie interesting in this connection to note the effect of temperature on the removal of the phosphorus from the iron. As is well known, no phosphorus is eliminated under the oxidizing influences prevailing in the Bessemer converter, while from 70 to 80 per cent. is removed in puddling. But we find, if in working cold short irons the temperature of the furnace is much increased towards the end of the process, that a considerable amount of the phosphoric acid is deoxidized and phosphorus again combines with the iron. This reverse process

is aided by a siliceous cinder arising either from the use of a very siliceous pig iron, or of an over-siliceous ore for fix. The fact which has been known for some time that only a basic cinder can retain phosphoric acid has given rise to the "basic lining" which now attracts so much attention in the Bessemer process. For the conditions affecting the removal of phosphorus from pig iron I would refer to the careful and complete experiments of I. Lowthian Bell, in England.

Notwithstanding the recent progress in the metallurge of iron the puddling process is essentially what it was three-quarters of a century ago—laborious, crude and unsatisfactory. The attempts at improvement in the process may be classified under two heads: 1. economy of labor; and 2. economy of fuel.

Increase of yield and improvement of quality are so intimately connected with both of these two classes that it is not easy to consider one apart from the other.

1. Economy of Labor.

For the successful accomplishment of the operation of puddling it is necessary to bring the molten metal into contact with the solid oxides by agitation effected either by human or mechanical agency upon a stationary hearth, or by giving motion to the whole body of the furnace. One of the first attempts for lessening the labor of the puddler is recorded in a drawing at Dowlais which has been traced back to the year 1834. It is a reverberatory furnace with a revolving hearth, driven with a vertical shaft by bevel gearing. Whether this machine was ever used I do not know, but it is of interest as showing that most of subsequent improvements are not new in principle. Coming to more recent times, we have the Richardson process of blowing air into the molten bath through a tubular rabble. The advantages claimed for this method are that it hastens the boil, reduces the labors, and produces a tough metal of uniform and high quality. After the iron has come to a boil the rabble is withdrawn and the working continued in the ordinary manner. I believe this process has never been used in this country and but sparingly in England.

Morgan's puddling machine consists of a reverberatory furnace of the usual form, which has an opening in the roof through which a vertical shaft is lowered with a horizontal arm. The shaft is set in motion by suitable machinery, and the arm revolves in the furnace, doing away with the labor of the puddler and helper until the heat is

ready for balling, when the shaft and arm are withdrawn, the opening in the roof closed, and the balling proceeded with in the usual manner. The wear and tear connected with this method must be enormous, and the results, I should think, not very satisfactory.

Griffith's and Whitham's devices are similar in idea, but different in mechanical details. Their object is to give an oscillating movement to a rabble of the ordinary shape by means of machinery, the puddler or helper merely guiding the rabble. The balling is accomplished in all cases by hand labor. None of the above-mentioned improvements do away with the skilled workman, but merely lessen the laborious work of the early stages of the heat, which requires brute force rather than experience.

In a work by Kohn upon the *Manufacture of Iron and Steel* will be found more detailed statements concerning these processes. That any of them has proved satisfactory I question. One of the imperfections common to them all is the difficulty of keeping the raw iron from gathering in the crevices of the fix and settling on the bottom and in the corners of the furnace into which the rabble does not enter, leaving the furnace at the conclusion of the heat in a very dirty condition. We all know the importance of a thorough working of iron in the jambs of a furnace, as it is there that the metal begins to gather when coming to nature, requiring careful working for good results. Another serious objection which may be advanced against these processes is, that they require the same skilled workmen to operate them as are needed for the old style of hand puddling. No increase in the number of heats is obtained, for the men, instead of encouraging experiments, look upon them with great distrust as inimical to their best interest, and when a workman and his tools do not agree good results cannot be expected.

About 1867 a change in the direction of improvement took place, and it was reserved for an American, Samuel Danks, to have the boldness to propose an entire revolution in the puddling process. The Danks furnace was the first rotary furnace to be put into successful operation, although its success was not assured until many improvements and alterations were made upon the original designs.

In England this same idea was elaborated, and several machines were brought out differing in details. The one of most novel construction was the Godfrey-Howson furnace, which had but one opening into which the heat enters and the products of combustion

escape, a blowpipe on a large scale being substituted for the ordinary fireplace. Later, in this country, we find a rotary furnace designed by the Edgemoor Iron Company, of Wilmington, Del., worthy of mention from the fact that this company is at present equipping their works with these furnaces, which would seem to indicate great confidence upon the part of the proprietors in the success of the rotary process.

2. Economy of Fuel.

In the utilization of coal for puddling two methods are employed. The one in almost universal use, where coal is directly burned on the grate of the furnace, is irrational and wasteful. The other method, consisting in the conversion of the coal into combustible gases, which are burned on the hearth of the furnace, though more economical and rational, is but seldom used.

The attempts which have been made to improve the old system may be divided into two classes: First, those having for their object the prevention of smoke by feeding the coal below the surface of the fire, which is always kept bright. The mechanical devices for accomplishing this object are found in the Frisbie & Sweet furnaces. The system has not come into general use. An objection in the case of coal forming clinkers is, that the clinkers are forced to the top of the fire. Second, those having for their object the utilization of the volatile matters of the coal by a partial coking of the coal before it reaches the fire. This is effected by the employment of a separate magazine in connection with the fireplace. The gases from the coal are caused to pass over the fire and are there burned. Of this variety of furnace may be mentioned the Wilson furnace, and of more recent date the Price furnace, which has given very good results.

When we consider, however, the cost of introducing these improved furnaces, and the trouble and annoyance of teaching workmen to use them, it is evident that we might just as well go a step further and introduce the gas system in its entirety. The great advantages to be gained in the use of gas in puddling are well known. We may distinguish here two systems, the continuous-acting furnace, of which Swindell's furnace is an example, and the well-known Siemens regenerative furnace.

Of the use of water-gas in the place of the ordinary generator-gas it is too soon to speak, but reference may be made in passing to the astonishing results said to have been obtained at Washington by the

Gill process, with gas containing as high as 75 per cent. of combustible gases, which we take *cum grano salis.*

What, let us now ask, is the present state of the puddling process, and what relation does its welded product sustain to the fused product of the Bessemer converter and the Siemens furnace? Will steel supplant iron?

In a paper on the Separation of Phosphorus from Pig Iron, read before the Iron and Steel Institute of Great Britain in 1878, by I. Lowthian Bell, occurs the following:

"The elimination of this metalloid from pig iron is, doubtless, a subject of great interest and importance to British smelters, having regard to the fact that nearly five-sixths of the metal obtained from their native ores contains so much of this impurity as to unfit it for the manufacture of steel, that form of iron which bids fair to supersede, in a great measure, the product of the puddling furnace."

If phosphorus cannot be removed, the question is easily settled; the production of steel is a limited one; and in the future, as at present, it will be made from the highest grades of our pig irons, and be used for certain special purposes, such as rails, etc., for which it has shown its great superiority over iron.

But, no doubt, many will at once say: phosphorus can be removed, the Thomas & Gilchrist process, with its basic lining, has overcome this difficulty. That phosphorus has been removed experimentally there can be no question; that it has been expelled successfully, from a commercial point of view, is open to doubt. Of the three processes established for its elimination, the Bell, the Krupp, and the Thomas & Gilchrist processes, the second has, from an economical standpoint, produced the best results.

There are some points in regard to all of them which, in the published results of experiments, have not been very fully touched upon, though they are of great importance. Is the increased cost of working greater than the difference in price between inferior brands of pig iron and those suitable for steel-making? This is, of course, a secondary consideration if the demand for such pig exceeds the supply, but it will be of vital importance if the reverse is the case. Is the removal of phosphorus uniform or does it vary, giving us results differing from day to day? What is the percentage of bad blooms made by these processes as compared with the usual method of working? How uniform is the quality of the final product as furnished to the con-

sumer? It will, perhaps, be said that sufficient experience has not yet been obtained to answer these questions, but until they are disposed of we must be very cautious in accepting the announcement made by inventors or operators to the effect that success has been achieved. Granted that a method of dephosphorization may be established upon a commercially successful basis (and present indications seem to point to such a conclusion), what will be the resulting product, and how well will it be fitted for its intended uses?

In advocating the use of high qualities of steel, and enumerating the advantages to be gained by employing it, the fact is frequently lost sight of that this superior metal is made from the highest grades of pig, obtained with the greatest care from the purest ores, and that the succeeding processes are worked out with the aid of the most improved plant. The metal is followed through all details of manipulation with the most thorough inspection and rigid chemical and mechanical tests. Material thus obtained is compared with wrought iron made from anything and everything. No chemist mixes the charge or analyzes the product, but a puddler is left to guard the interests at the most vital stage of the process. It is his aim to produce the greatest weight, with the least labor, in as short a time as possible, and with such work no one can blame him. It is not astonishing that under such conditions iron is so much inferior in its physical qualities to steel. Even taking the same grade of pig metal for the manufacture of wrought iron as is now used for steel, the mild grades of the latter suitable for structural purposes will, no doubt, give higher results by mechanical tests, but the difference between the two will not be as great as many are apt to think.

On the other hand, if in the future, by means of dephosphorizing processes, we shall use all sorts of pig iron for steel, shall we not introduce a dangerous element of uncertainty into its manufacture which we do not have to deal with at present? When it is considered how very slight a change in the percentage of some foreign substance may produce a considerable variation in the quality of steel, uniformity in a metal derived from such impure raw materials must be difficult to attain. The homogeneous nature of steel, as compared with the many-pieced structure of iron, is claimed as one of its advantages. Homogeneity in steel may be a cause of weakness, and the lack of homogeneity in iron a source of strength. A steel bloom, to all external appearance perfect, may be within entirely bad, either

from piping in the moulds, or from other causes of a similar nature. Chemical analysis will not show this defect, and a bar produced from the same, although sound as far as can be seen, may fail in service suddenly and without warning. On the other hand, the possibility of a wholly bad iron bar diminishes just in proportion as the number of pieces in the pile from which it is made increases.

For a material for structural purposes the term uniformity should take the place of homogeneity. A material exposed to abrasion, such as a rail receives, requires the latter quality, but one subjected to strains of compression and extension, tension and bending, wants uniformity more than any other property. If one bad member is contained in a structure the strength and homogeneity of the whole is of no avail. For many purposes in construction steel may be used to very good advantage, notably for members liable to wear and parts running in bearings. But whenever it is applied in parts of varying outline, where sudden changes in form take place, planes of weakness are developed at all those points at which anything like a corner occurs, unless large fillets are used and great care is taken. It must not be forgotten that the structures hitherto erected of steel, have been, as it were, experimental, and have therefore been put up with the closest inspection and caution. If it should be generally adopted, this same care could not be exercised unless an entire revolution in existing modes of manufacture takes place. The rough handling which iron for structural use receives in manipulation would be fatal to steel. Existing plant and methods of working must be abolished, and workmen be educated in the proper handling of the new products.

Looking upon the above objections as a few of the more important ones yet to be met before a more general use of steel can take place, it will be apparent that its substitution for wrought iron will be very slow and gradual. The puddler and his furnace yet have many years before them. No one could regret it more than the writer. No other process in iron metallurgy requires so much work per ton of metal produced. It seems absurd to think that the labor of two men for ten hours is necessary tr produce a ton of wrought iron, and that for one ton of pig iron used one ton of coal is consumed! It is not worth while to consider those methods which aim merely to lighten but do not do away with the labor of the puddler. They may have some advantages, but they will never come into general use. What is needed is a method which is governed by intelligence, but which requires only

ordinary labor for its working. The rotary furnace process is the only one which at present aims at this result, but its complete success is open to doubt. The wear and tear of the complicated mechanism and revolving surfaces is a source of expense, and the lining is composed of a material not well calculated to resist heat. The quality of the iron, however, is good, and counterbalances many of the attending disadvantages, although it will not, as was at one time hoped, answer for making bars without weld. It must be cut and piled as ordinary iron, or the work upon it will not suffice for good results.

We are now in the midst of an epoch of uncertainty; a few years more and the success or failure of steel to supplant wrought iron will be established beyond a doubt. Its success depends upon the results which shall be obtained from the working of all grades of pig iron; and its failure is certain if uniform quality cannot be produced. For the present, therefore, the system of puddling must continue as of old; but every ironmaster, not only of this but of other countries, will most gladly welcome the process, whether it be of steel or of iron, which shall do away with the weary toil of so many thousands, and usher in a brighter and a better era than could ever be accomplished by the puddling process as invented by Henry Cort.

Relation of Spectral Rays to the Constitution of Nebulæ.—Ch. Fievey has made the spectral rays of hydrogen and of nitrogen the subject of a special careful investigation. By attaching to the spectroscope a contrivance which enables him to regulate at will the quantity of light received, he observed that the spectrum of hydrogen was modified and simplified in proportion as the brilliancy diminished. The H line first disappeared, then C, and finally only F was left. It is well to remember that the F line is the only one of the hydrogen lines which has been observed, in a large number of nebulæ that have been examined by the spectroscope. The spectrum of nitrogen gave results similar to that of hydrogen. It is, therefore, not strange that we should meet, in nebulous spectra, only the rays which are most persistent in diminished light. Such rays may suffice to establish the presence of the body to which they belong, and the disappearance of the others may be explained by their extinction in traversing the intervening spaces.—*Bull. de l'Acad. Belg.* C.

SLAG CEMENT.

We have on several occasions directed attention in this Journal to the very important question of the satisfactory utilization of the slag produced from blast furnaces. In past years this product has been accumulating to a vast extent, and the ironmasters have been put to enormous expense and inconvenience in providing places of deposit for many millions of tons of this, until very recent date, comparatively useless article. It is true that in some few instances it has been employed in filling up shallow bays, and even for making roads in the immediate vicinity of the works where it is produced, and where other more suitable material cannot be conveniently supplied, but for both these purposes the demand has been extremely limited, and in the vast majority of cases it has been got rid of as so much rubbish.

One very important use to which blast furnace slag has been proposed to be put has been in the production of bricks for building purposes, and for this application Mr. Charles Wood, the manager of the Tees Iron Works, Middlesbrough, obtained a patent in the year 1873, and full description of the processes employed by Mr. Wood have appeared in our columns. More recently we had occasion to speak of a patent obtained by Mr. Frederick Ransome (who for nearly forty years past has been prominently before the scientific world as the inventor of several ingenious and valuable processes for the manufacture of artificial stone) for the production of an eminently hydraulic cement, in which the slag sand from the blast furnaces forms a conspicuous and very important feature, and of this cement we have now something more to say. Good Portland cement, which now enters so largely into the construction of all hydraulic and substantial building operations, is, as our readers are aware, a compound of silicate of lime and alumina, and contains about:

	Per cent.
Lime,	62
Silica,	22
Alumina,	8
Oxide iron,	3
Potash, soda, magnesia, etc.,	5
	100

This composition is generally obtained by intimately mixing chalk and clay, this mixture being burnt at a very high temperature into an extremely hard clinker, which is subsequently ground to a fine powder. Mr. Ransome having been applied to, to produce a cement possessing the strength and valuable hydraulic properties of Portland cement, was not slow to appreciate, and avail himself of the valuable results obtainable by a combination of the slag sand from the blast furnaces with an additional quantity of lime. He at once commenced a series of experiments, and, as we stated in this Journal in December, 1879, he succeeded in producing a cement of a most delicate color, possessing extraordinary hydraulic powers, and acquiring great strength, increasing with age. Thus at three days it was stronger than Portland cement at seven days; in seven days it was stronger than Portland cement at three months; at fifteen days it was stronger than Portland cement at twelve months; and at twenty-eight days it was stronger than Portland cement at seven years. The foregoing results were obtained by mixing the slag sand, supplied by the Tees Iron Company, with the white chalk of Essex, in the proportion of about 1 ton of slag sand to 1¾ tons of chalk, and subsequently burning the same in an ordinary cement kiln. The composition of the slag sand above alluded to was, as stated in our former notice, found by analysis to be:

Silica,	38·25
Alumina,	22·19
Lime,	31·56
Magnesia,	4·14
Calcic sulphide,	2·95
Protoxide iron, etc.,	·91

Mr. Ransome has, however, ascertained that he is able to obtain a still stronger cement by the employment of slags containing a higher percentage of alumina. It was long since discovered and reported by M. E. Frémy and MM. Rivot and Chatony in their admirable works on cements, "That aluminate of lime is the principal hydraulic agent in cements." M. E. Frémy attributes the setting of a hydraulic cement to two chemical actions: (1) To the hydration of aluminates of lime, and (2) to the action of hydrate of lime upon the silicate of lime and the silicate of alumina and lime which exists in all cements, and in this case act as puzzolanas. The results arrived at by Mr. Ransome fully corroborate these views, and by attaching full importance to the presence of alumina, Mr. Ransome has, as we have mentioned,

succeeded in greatly increasing the strength of the new cement. Samples which we have seen show remarkable hardness and closeness, and the material in fact promises to be an exceedingly valuable one. By the employment of blast furnace slag sand the great proportion of the expense involved in the production of the clinkers used in the ordinary process of manufacturing cement is avoided; the cost of fuel and expense of grinding being hence reduced, while a useful application is found for what has been until recently a waste product. The Ransome cement, as made from the blast furnace slag sand without the admixture of any coloring matter, is of an exceedingly pleasant tint, while any desired color can be given to it as desired by the addition of suitable coloring materials. Altogether, Mr. Ransome may be said to have created a new branch of industry of value alike to engineers, architects, ironmasters, and cement makers, and we are not surprised to learn that he is meeting with the co-operation of many of our leading men interested both in our iron and cement manufacture.—*Engineering.*

Influence of Capillarity upon Dyeing.—Gustav Engel has conducted an interesting series of experiments upon animal and vegetable substances, with a view to ascertain the principles involved in dyeing. Microscopical examination of infusorial earth showed that the coloring matter was attached solely to the interior of capillary tubes. The experiments all agreed in proving that the facility of absorbing and retaining dyes depends almost entirely upon physical structure and especially on capillarity.—*Bull. de la Soc. de Mulhouse.* C.

Phosphorescence of the Glow-worm.—Jousset de Bellesme has repeated the experiments of Matteucci upon the glow-worm with some precautions which lead him to more satisfactory results. He removed the cephalic ganglia so as to destroy all voluntary phosphorescence, and substituted the passage of a moderate electric current through the body, or in the luminous organ, thus producing a brilliant phosphorescence. When the insect thus prepared was plunged into carbonic acid, or into either of the inert gases nitrogen and hydrogen, the electric excitement produced no light. His investigations lead him to regard phosphorescence as a general property of protoplasm, consisting in a disengagement of phosphuretted hydrogen.—*Comptes Rendus.* C.

Variations of Gaseous Compressibility.—E. H. Amagat describes his experiments with various gases under extraordinary pressures. He finds that the greatest variations from the action of hydrogen are found in the gases which are nearest liquefaction. This is shown very clearly by the curves of formene and ethylene. Nitrogen and carbonic oxide show much smaller variations; those of oxygen are more considerable. The variations of air are intermediate between those of its constituent gases; the oxygen and nitrogen seem to be compressed separately, as if they were entirely independent of each other. The minimum ordinate of air is situated between the analogous ordinates of oxygen and nitrogen and sensibly nearer that of the latter gas.—*Ann. de Chim. et de Phys.* C.

Measurement of High Pressures.—In Cailletet's experiments upon the liquefaction of gases he used a manometer which enabled him to measure pressures of 1500 atmospheres with a probable error of not more than one-half of one per cent. It was constructed upon a principle which was suggested by M. Marcel Deprez. When water is compressed under a piston which is perfectly cylindrical and which works in a cavity drilled in a metallic mass, so that the annular space is very small, the water will escape only very slowly through the narrow passage. With this apparatus, which works without friction, it will be possible, by loading the valve, to weigh the pressures which tend to raise it. The apparatus which he used consisted of a cube of melted steel of 0·2 metres (7·9 inches) in thickness, in which a cylindrical aperture is drilled to receive the steel piston, and adjusted so precisely that the breadth of the annular space between them is less than $\frac{1}{200}$ of a millimetre (·0002 inch). A very sensitive lever receives at one of its extremities weights which exert upon the valve pressures that can be exactly measured. He placed under the piston a piece of gold-beater's skin, which offers an inappreciable resistance to flexure and which prevents the escape of water through the valve. In order to ascertain the precise moment when the piston is raised, he fixed upon the frame an insulated copper screw, against which the lever struck at the very moment when it was moved by the piston. The contact gave passage to a current which sounded an electrical bell. He found by a great variety of experiments that the indications for different pressures were very uniform.—*Ann. de Chim. et de Phys.* C.

French Railways.—The new railways now under contract will increase the French lines from 22,193 kilometres (13,790·73 miles) to 40,000 kilometres (24,855 miles). Most of the work will be done under the superintendence of the government agencies, and the lines will be managed under state supervision, but not at government expense. The freight tariff is lower than in any other country except Belgium.—*Chron. Ind.* C.

New Use of Nickel.—Nickel is more infusible than iron, more malleable, more ductile, tougher, and not affected by atmospheric influences. M. Fleitmann has found that when melted it absorbs some carbonic acid, and if a small quantity of magnesium is then added the metal becomes remarkably ductile and malleable. It can be drawn out into very fine wire or beaten into extremely thin leaves, and can be readily welded either to nickel or to iron.—*Chron. Ind.* C.

The Longest Geodetic Arc.—By the joint labors of Spanish and French engineers, under the direction of Ibañez and Perrier, science possesses the measurement of a meridional arc of 27°, the longest that has yet been measured on the earth and projected astronomically in the heavens. Biot and Arago, on their return from Spain, anticipated the possibility of such an undertaking, if the revival of Spanish civilization should ever open the way, and their dream has been realized, after ten years' work, in an arc which extends from the northernmost of the Shetland isles, in lat. 61°, to the Saharan desert, in lat. 34°, covering nearly one-third of a quadrant.—*Comptes Rendus.* C.

Coal in India.—Theodore W. H. Hughes begins a paper on the coal fields of India by saying: "It will doubtless surprise many to learn that both in the superficial extent of its coal measures and associated rocks, and in the actual amount of its coal, India is surpassed by few countries, and that with respect to the size of some of the seams it stands pre-eminent in the history of mining." Even the United States cannot boast of seams 100 feet, 120 feet and 160 feet thick, like some that occur in Bengal. He calculates that the coal fields of India cover 35,000 square miles, and according to estimates drawn up by Dr. Oldman there cannot be less than 20,000,000,000 tons of coal in the Empire. Much of the material, however, is of an inferior quality and fit only for very rough use.—*L'Ingen. Univ.* C.

New Theory of the Formation of Hail.—Colladon supposes that the heavy rains and the hail-storms which follow them produce, by the very effect of their fall, a vertical wind due to the air which they draw from the upper regions of the atmosphere by their own friction. This vertical wind, which extends from the cloud to the ground, necessarily leaves behind it a partial vacuum, which produces an influx of air during the whole continuance of the storm.—*Les Mondes.* C.

Relation of Gases to Pressure, Volume and Temperature.—At the last meeting of the German naturalists and physicians Clausius read a paper upon Mariotte's law, in which he gave the ratio

$$p = R\frac{T}{v-a} - \frac{c}{T(v+\beta)^2}$$

p representing the pressure, v the volume, T the absolute temperature, R, a, β and c constants depending upon the nature of the gas. He found, by a series of experiments at different temperatures with carbonic acid gas, that the results were expressed much more closely by his formula than by that of van der Waals.—*Ann. d. Phys. u. Chem.* C.

Superficial Vibrations. — Prof. Francis-Honoré Lechat has studied this subject, both theoretically and experimentally, and finds that his mathematical theory is completely confirmed by his experiments. If, for a given form of surface, we compare the durations of the periods at different depths, these periods are found to increase with the depth, but in a diminishing ratio, so that at a moderate depth the duration ceases to vary. This result agrees both with the theory of Lagrange and with that of Poisson. But the limiting depth depends upon the form of surface, the depth diminishing with the complication of the form. This agrees with the theory of Poisson, but is not indicated by that of Lagrange. Lagrange and Poisson are both in error as to the relation between the duration of the period and the form of the surtace for any fixed depth. Their errors seem to have arisen from supposing that the molcules of the free surface remain constantly upon the surface during the vibration. We must therefore conclude that this hypothesis is not legitimate, and that it is necessary to admit, with the brothers Weber, that the molecules of the surface quit it in order to penetrate into the mass of the liquid.—*Ann. de Chim. et de Phys.* C.

Newly-discovered Nervous Energy.—During the past year Dr. Brown-Sequard has often noticed that the irritation produced by a transverse section of the base of the brain produces opposite effects upon the nerves which are before and behind the section. Following the lead of these indications, he finds that some parts of the nervous system are able, when irritated, to produce a sudden notable augmentation of the properties, or of the motion or sensitive activities, of other parts of the system.—*Comptes Rendus.* C.

Metallic Varnish.—Some years ago workmen at Natal observed that many of the *Euphorbiaceæ*, when cut by iron or steel, leave on the blade a coating of adhesive gum, which it is very difficult to remove, and which is an effectual safeguard against rust. The gum can be dissolved in alcohol and applied as a varnish to the hulls of vessels or other metallic surfaces. The alcohol soon evaporates, and leaves the gum in close adhesion. It is, moreover, so bitter that the white ants will not attack any object coated by it.—*Les Mondes.* C.

Artificial Wines.—The ravages of the *phylloxera* have greatly increased the demand for "artificial wines" and brandies, or those made from raisins. E. Martin undertakes the defence of these products, and says that chemical analysis can show no difference between them and those which are made from fresh grapes. He states, however, that it is better to add an equal portion of fresh grapes, so as to quicken the fermentation which has been rendered sluggish by drying. When this is done, he defies the most skillful connoisseur to detect two specimens of artificial wines among eight others of natural wines. —*Chron. Indust.* C.

Book Notices

LINKAGES; the different Forms and Uses of Articulated Links. By J. D. C. De Roos. Translated from "Revue Universelle des Mines," and reprinted from "Van Nostrand's Magazine," No. 47.

ON THE MOTION OF A SOLID IN A FLUID; and the Vibrations of Liquid Spheroids. By Thomas Craig, Ph.D. Reprinted from "Van Nostrand's Magazine," No. 49.

These two numbers of Van Nostrand's Science Series contain important discussions of their respective subjects. The treatise on link-

ages gives a very good summary of the knowledge upon that subject six years ago, and it contains much information that will be new to most American readers. The book might, however, have been made much more valuable if the translator had compiled, from the JOURNAL OF THE FRANKLIN INSTITUTE and other sources, some of the more recent discussions by Prof. Marks and others.

Dr. Craig's volume gives a brief account of several of the great problems of hydrodynamics, the figure of the earth, flow through an orifice, motion of a solid in a fluid, etc. He has greatly added to the value of his own labors by giving full references to many of the most important memoirs, from which further information may be obtained in regard to the various points that are treated. In some of the problems he has simplified the necessary integrations by introducing curvilinear co-ordinates, and transforming the different equations of fluid motion by the aid of such systems of co-ordinates. Some idea of the extent of his research in preparing the volume may be formed from the following partial list of authors whose works are cited. Todhunter, Dirichlet, Maxwell, Kirchhoff and Boltzmann, Bjerknes, Laplace, Resal, Lionville, Mayer, Sir Wm. Thomson, Tait, Riemann. With the exception of a few typographical inaccuracies the work is worthy of great commendation, containing as it does, a very complete discussion of important problems which are continually recurring in many departments of modern scientific investigation. C.

WATER ANALYSIS FOR SANITARY PURPOSES; with Hints for the Interpretation of Results. By E. Frankland, Ph.D. 12mo. Philadelphia: Presley Blakiston. 1880.

In this volume the distinguished Vice President of the Institute of Chemistry of Great Britain gives us the leading particulars in the analysis of water, stating that the exhaustive chemical examination of it is one of the most tedious and troublesome operations a chemist is called upon to perform, from the great multiplicity of separate substances which may be present either in solution or in suspension, the minute proportion in which they may exist and the difficulties attending their exact determination; but if the object is only to ascertain the suitability of the water for domestic or manufacturing purposes, many of the most tedious of the operations may be omitted.

The work is divided into two parts and an appendix. In Part 1 the various steps in water analysis without gas apparatus are given, and in Part 2 the processes requiring it. In the Appendix are mentioned the various reagents employed in water analysis, while useful tables, etc., are given. We have been much pleased with this work and the clear style in which it is written by its learned author, who is, evidently, a master of this subject. N.

A Practical Treatise on Natural and Artificial Concrete; its Varieties and Constructive Adaptations. By Henry Reid. New edition. 8vo. London: E. & F. N. Spon. 1879.

The great importance of this subject and the success of the author's previous work, published more than ten years ago, is the reason of the appearance of this handsome volume, in which the most recent knowledge is collected and the whole worthily treated by one who has devoted much attention to it. In tracing the progress of scientific concrete making, the author claims to have shown that the success achieved by these prosperous industries has been due to the steady adherance of their several adoptors to accurate rules, which should guide all manufacturers, and due acknowledgment is made of the valuable information he has obtained from General Gilmore's treatise on "Coignet Beton," as regards the industry in the United States. The table of contents and a full index show the care with which the work has been prepared, while the colored plates and numerous illustrations throughout the text prove that the publishers have spared no expense in making this volume worthy of being considered a practical treatise on a subject destined to become of the greatest importance with the advances that are now being made. We cordially commend the volume to the attention of our readers. N.

Health and Healthy Homes; a Guide to Domestic Hygiene. By George Wilson, M.D. 12mo. Philadelphia: Presley Blakiston. 1880.

This useful little volume, by the author of the "Handbook of Hygiene and Sanitary Science," will be welcome in many a home, and we trust will find numerous readers, as a concise and practical treatise on a subject upon which information is all-important. The author

has wisely avoided technicalities, writing as he does for all classes of readers, and has performed his task in so careful a way as to leave little to his American editor, Dr. J. G. Richardson, to add, excepting a few additions respecting matters wherein variations of climate, sanitary regulations, etc., call for notice. We have been most favorably impressed with the chapters on the "Causes of Disease" and "Food and Diet." Under the head of intemperance he does not hesitate to express his opinion that the moderate use of alcoholic stimulants has not been proved to be detrimental to the health of persons partaking of them daily, but who are careful never to exceed a certain limit; but, on the contrary, that they often prove a valuable aid to digestion, making the wheels of life to run more smoothly without in any way injuring its machinery, an opinion in which temperance people will be sure to differ, although as he adds civilization itself exhibits a strange unison with the consumption of alcohol.

The book, like all Mr. Blakiston's publications, is tastefully got up and of course well printed. N.

Franklin Institute.

HALL OF THE INSTITUTE, June 16th, 1880.

The stated meeting was called to order at 8 o'clock P.M., the President, Mr. William P. Tatham, in the chair.

There were present 104 members and 17 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and announced that 19 persons were elected members of the Institute at their last meeting.

The Secretary reported the following donations to the Library:

Report of the Board of Commissioners of the Cincinnati Industrial Exposition. 1879. From the Board.

Papers relating to the Foreign Relations of the United States. From the Department of State, Washington.

Engravings of Ancient Cathedrals, etc. By John Coney. London. From Dr. Isaac Norris.

Sixth Annual Report of the New Jersey State Board of Agriculture for the year 1878. From the Board.

Life and Work of Joseph Henry. By F. L. Pope.

San Francisco Chronicle: its History, etc. 1879.
From the Office.

Memoirs of the Yellow Fever. By Wm. Currie. Philadelphia, 1798. From Dr. Isaac Norris.

Annual Report of the Water Department of the City of Philadelphia for 1879. From the Chief Engineer.

Eighth Annual Report of the Board of Directors of the Zoological Society of Philadelphia. 1880. From the Society.

Project for a Technological Institute and Museum of Useful Arts in Philadelphia. 1875. From J. W. Nystrom.

Annual Reports of the Wisconsin Geological Survey for 1878 and 1879. By T. C. Chamberlain. From the Survey.

Photometric Researches. By Wm. H. Pickering.
From the Author.

Cambridge Boiler Explosion. Boston, 1878.
From A. Williams & Co.

Engine and Boiler Insurance Company. Chief Engineer's Report. 1880. From the Company.

First and Second Annual Reports of Bureau of Statistics of Labor and Industries of New Jersey. 1878–9. From the Bureau.

Report of J. H. Comstock upon Cotton Insects. Washington, 1879. From the Department of Agriculture.

Statistical Abstract of the United States. 1879. Washington.
From the Treasury Department.

Bulletin No. 4 United States Entomological Commission.
Introduction to the Study of the Sign Language. By G. Mallery. Washington, 1880. From the Department of the Interior.

Annual Report of the Secretary of the American Iron and Steel Association. 1880. From the Association.

Handbok för beräkning och byggnad af Turbiner och Turbinpumpar. By C. A. Angström. Stockholm, 1880. 2 vols.
From the Author.

Congressional Record of March 4th, 1879; containing Memorial Exercises in Honor of Joseph Henry.

American Ephemeris and Nautical Almanac for 1879.
From Wm. Charlton, Jr., U. S. R. M.

Transactions of the Connecticut Academy of Arts and Sciences. Vol. 1, Part 2; Vol. 2, Parts 1 and 2; Vol. 3, Parts 1 and 2.
From the Academy.

Report of the Great Trigonometrical Survey of India. Vol. 5.
From the Viceroy and Governor-General of India.

Report of the Board of Commissioners of the State Survey of New York. 1877.
Report of the New York State Survey for 1878.
From J. T. Gardner, Director.

Reports P_2, Q_2, Q_3 of Second Geological Survey of Pennsylvania.
From the Board.

Specifications and Drawings of British Patents. Vols. 2 to 21. January to May, 1879. And Disclaimers, etc. No. 2378 of 1868; No. 1823 of 1869; No. 1491 of 1870; Nos. 2044 and 3217 of 1875; No. 3875 of 1876; Nos. 1110, 2909, 4169 and 4783 of 1877; No. 1715 of 1878, and No. 763 of 1879.
From the Commissioners of Patents.

Reports of Commissioner of Education for 1875 and 1876. Washington, 1876 and 1877. And
Record of Officers and Men of New Jersey in the Civil War, 1861 to 1865. In 2 vols. Trenton, 1876.
From W. S. Cooley, Philadelphia.

Mr. W. Barnet Le Van exhibited drawings of some express locomotives, and read a short paper describing them. His paper also described the tender built to pick up water from a trough while the train is in motion.*

Mr. Le Van's prophecy, at the last meeting, that in a few years trains would be run between New York and Philadelphia in sixty minutes, having been criticised, he read a short addition to his paper on the subject of imperfect railroads, showing that one-half of the average resistance to traction on level railways is due to imperfections in the condition of the road bed, and also that if all the railroads were level only one-half of the present engine power would be required, with a corresponding reduction of working expenses. He had no doubt that road beds would be so perfected as to permit the high rates of speed he had prophecied, and he quoted from eminent engineers to show that they looked upon a perfect railroad as a possibility of the future. The advances already made give promise that we will go still further in the same direction.

Mr. Hector Orr inquired whether the increased speed of railway trains led to an increased loss of life by accident.

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* See page 21.

Mr. Le Van said that he had not studied the statistics of the subject, and therefore could not answer the question specifically, but his impression was that there would be no increased danger, the greater speed going along with improvements in road beds, etc. He believed that there was less loss of life now on the Pennsylvania Railroad than before the fast trains were introduced.

The question was further discussed by Messrs. Cooper and Nystrom.

Mr. Theodore T. Woodruff, inventor of the parlor sleeping car, described, with the aid of illustrations, his steam motor for cultivation of the soil—an immense machine, estimated to weigh, with water and fuel, 51,500 pounds, and, as arranged for plowing, estimated to run 132 feet per minute. In the drawings the machine was represented with 15 plows, each designed to turn 14 inches wide, so that the machine would prepare ground for a width of 17 feet 6 inches at the rate mentioned above. Among the peculiarities of the machine is the system of truss bracing, to secure rigidity, and the use of track drums, with sun and planet motion of cog wheels on a rack, whereby it is designed to have the machine lay down and take up the track on which it runs. The track drums are broad-faced and carry tracks on which the machine rests. They are set in motion by an annular rack, in which the driving wheels gear. The motor is guided as well as driven by steam, and the plows are adjustable (within limits) to any desired depth. The motor may also be adapted for ditching, grinding, threshing, sawing, etc.

The President inquired whether the machine described had ever been built.

Mr. Woodruff replied that it had not, but he had made all the calculations as to friction, etc., over dirt roads and fresh earth.

Mr. Cartwright inquired how much land the machine was calculated to plow, and Mr. Woodruff replied three and a fraction acres in one hour.

The Secretary then presented his report on inventions and novelties which had been sent to the Institute for exhibition.

Among these was the Rhyston mangle, a machine designed to iron clothes without heat. The clothes to be smoothed are wrapped on a roller in a linen cloth, and are then rocked to and fro, under pressure, on a concave table. The Rhyston machine for doing this work is compactly built, comparatively small and very easily operated.

Mangles of various kinds are largely used in Europe, but in this coun-

try have not as yet been introduced to any great extent, except in hotels and large laundries. They undertake to do by pressure alone what is done with the sad iron by heat and pressure, and are used for everything except starched and ruffled garments. Where much ironing has to be done, mangles prove economical, as they save a great expenditure for fuel. They are also economical of time, a large roll of articles to be ironed being pressed at once and in a few minutes.

Jewett's patent water filter, which combines a removable and cleansable filter, with a charcoal filter and a porcelain-lined reservoir for filtered water and ice. By the combination of the two filters the grosser impurities are kept from accumulating in the filtering bed.

Wooden pulleys, with taper sleeve fastenings, from the Taper Sleeve Pulley Works, Erie, Pa., were then described. The web of the pulley is constructed of segmental pieces, in each of which the grain is in a radial line from centre to circumference. The rim is constructed by building up a series of rings on either side of the web, and the completed pulleys are afterwards turned true and finished with shellac to protect them from the weather. The taper sleeve coupling and pulley fastenings are constructed on the same principle. Two ring-nuts, to be screwed upon a shell having a taper bore, smallest in the centre, and two split sleeves, comprise the parts. The ends of the shafts to be united are slightly dovetailed, and, being put in position in the shell, the split sleeves are driven into position by the screw-nuts, and serve as wedges to keep the shafting united in the shell. The taper sleeve pulley fastening is identical in principle. The absence of set screws or similar devices for uniting shafting does away with dangerous projections to catch belts or clothing, and leaves the shaft uninjured by the cutting of key ways, etc.

I. P. Wendell's lubricating journal box for cars was shown in model. These boxes are now being tried experimentally on cars of the Union and Tenth and Eleventh Street Passenger Railway Companies. The motion of the car on its springs is utilized to pump up from the journal box the oil used to lubricate the axles, the oil being used over and over again until the box needs replenishing. The amount of oil to be pumped in successive jets is regulated by enlarging or diminishing the orifice through which it is thrown upon the axle. The apparatus is quite simple, and adds very little to the cost of the boxes.

Weston's differential pulley blocks, both direct and geared, were

shown. By their use a man can lift from 2000 to 5000 pounds, and they have the advantage over the ordinary pulley block that when you let go the chain the load still remains suspended, and it can be lowered only by pulling on the opposite side of the slack chain. In hoisting, the chain is taken up on the larger and paid off from the smaller of the wheels, the effect on the load being due to the difference in their diameters. In geared pulleys an extra wheel is added.

Several different styles of Brown's staple binder, for inserting wire staples in business and law papers, etc., were exhibited, and Partridge's patent pencil pointer.

Robinson's combination brace, wrench and hand vise was shown; also the Enterprise Manufacturing Company's fruit press, and a new style of carriage wrench, through the kindness of Truman & Shaw.

Alfred Wilkinson's metallic piston rod packing is made wholly of metal, and consists of cylindrical socket cases having annular anterior recesses, on which the periphery of the preceding one is made to fit so as to form separate and independent compartments. In the compartments are fitted Babbit metal rings, divided in only one place and arranged to break joints. These Babbit rings are encircled by a brass ring, cut in one place only and also arranged to break joints. The rings are held in contact with the piston rod by means of band springs. The whole is readily placed in the ordinary stuffing box and held there by the usual gland, the latter being used without alteration. It is claimed that the packing is entirely free from steam pressure, works with little or no friction on the rod, and secures an absolutely steam-tight joint.

Haines' patent self-locking hook was shown and described. The two arms are connected by a collar having on one of its sides ratchet teeth, which are engaged by similar teeth on the shank of the hook, which is capable of turning, the weight of the traces, etc., holding it securely locked.

Mr. W. W. Warner, representing the International Chemical Company, of New York, exhibited samples of dress goods treated with neptunite, or "fibre mail," to make them waterproof, while at the same time permitting the circulation of air through them. The goods shown were silks, satins and velvets, some of them of delicate shades. They were unchanged in appearance by the application of neptunite, which is a new product of rubber, but perfectly resisted the action of water, as Mr. Warner showed by sprinkling water upon them.